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SeisTool

Seismic – Rock Physics Tool

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SeisTool: Seismic – Rock Physics Tool

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Supports Exploration and Development Geoscientists in identifying or characterizing reservoir properties from seismic data. Reduces chance of user error and increases productivity by eliminating book-keeping and reducing display set-up time.

- Data are computed and displayed on the fly. There is no book-keeping. This results in faster analysis and less chances of mistakes.
- Pre-defined templates reduce display set-up time.
- Parameters for a given module are input in a single GUI.
- Data input are: rock properties (V_P, V_S and ρ), the results of a petrophysical evaluation (porosity, mineralogy and fluids – type and saturation) and a target (pay) flag.

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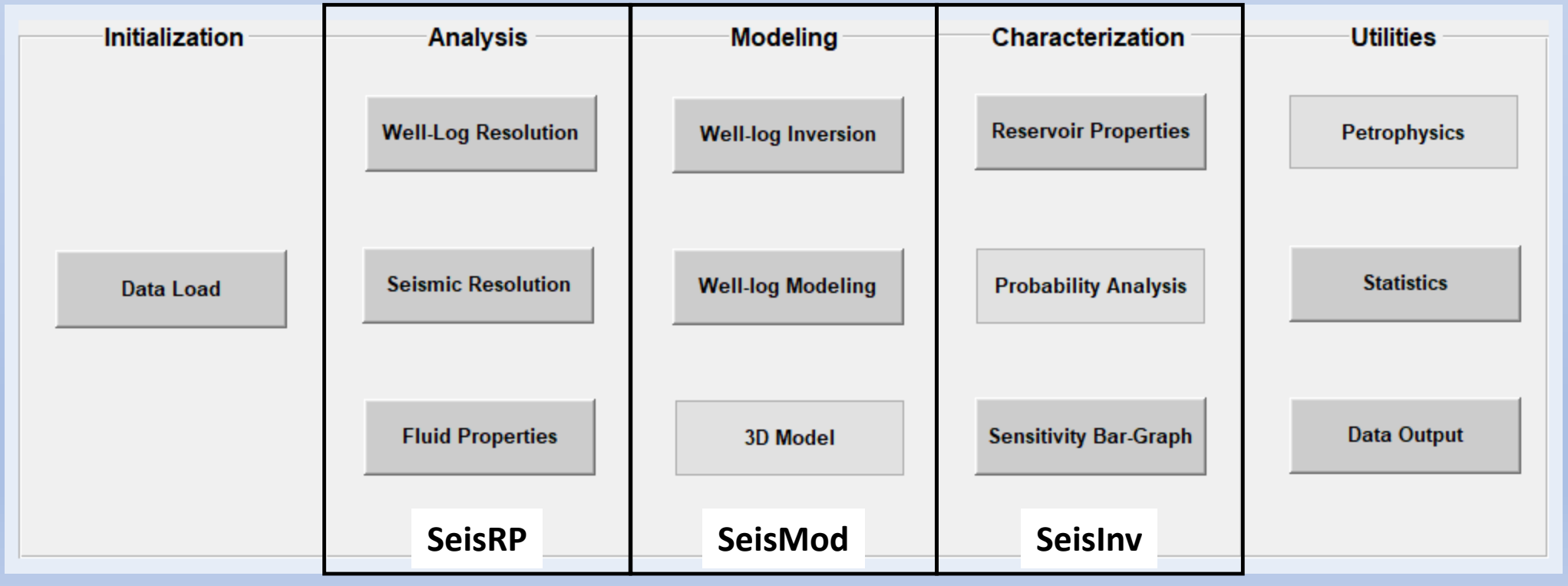
Consists of three modules, each with three programs. The analysis and modeling modules (SeisRp and SeisMod) are based on state-of-the-art rock physics relationships. These support the reservoir characterization module (SeisChar) in which parameters to compute reservoir properties (ϕ, lithology and fluids) are estimated through linear inversion of attributes computed from well-log or synthetic data



State of development to October 2019 Dark gray buttons correspond to operational programs

Generalized exploration/development workflow to estimate reservoir properties

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Simplified workflow showing the function that **SeisRP**, **SeisMod** and **SeisChar** have in supporting estimation of reservoir properties using seismic data

Petrophysics
(ϕ, S_W, lithology)

Rock Properties
(V_P, V_S and ρ)

Compute and evaluate attributes **SeisRP**

Well-log Resolution

Sensitivity analysis **SeisMod**

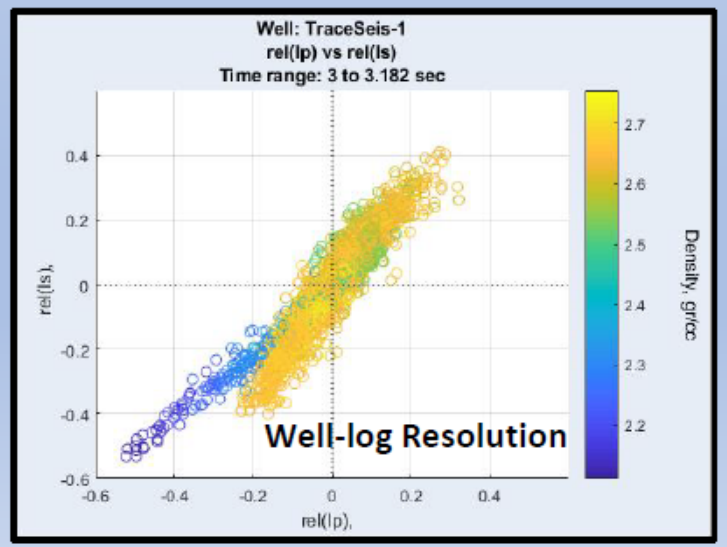
Seismic Resolution

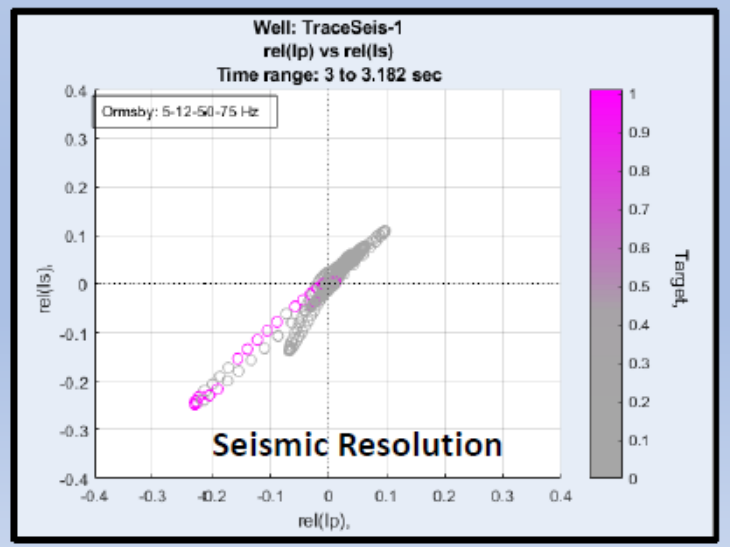
Determine optimum attributes **SeisChar**

Compute lithology and porosity cubes

Attributes from seismic

Compute probability cubes





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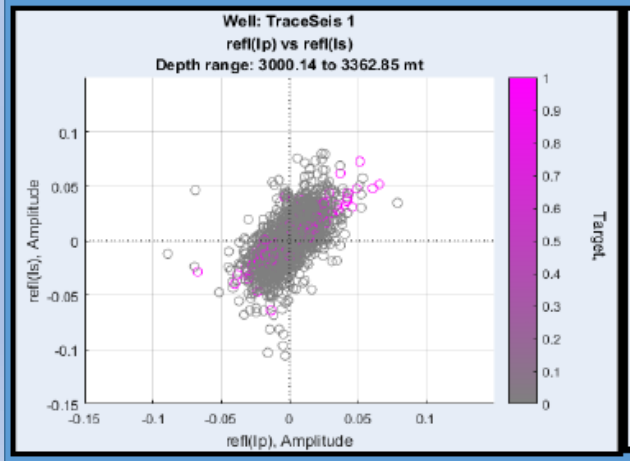
  - **Computes reflectivities, relative properties and absolute properties**
  - Generates attributes from wireline or modeled data at well-log or seismic resolutions in depth or two-way-time
  - Fluid substitution. Different fluids and saturations
- SeisMod
- SeisChar
- Utilities

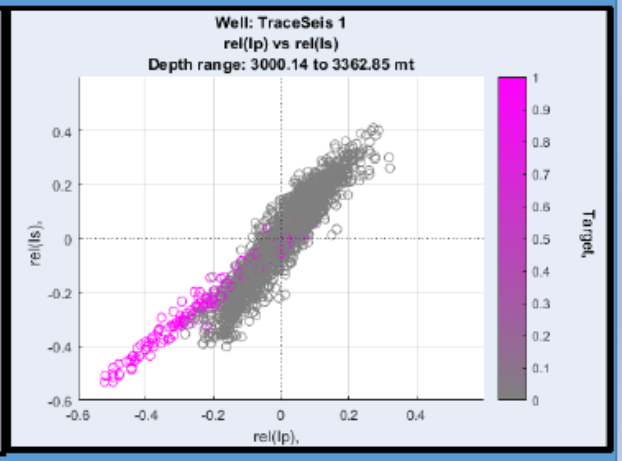
SeisRP computes reflectivities and absolute and relative properties.

Some observations about relative properties

- Measure interval properties
- Do not require a Low Frequency Model (LFM)
- Easy to compute from AVO attributes
- Better estimation of reservoir properties (SeisChar)



Reflectivities Ip, Is



Relative Properties Ip, Is

SeisRP: Analysis at well-log resolution

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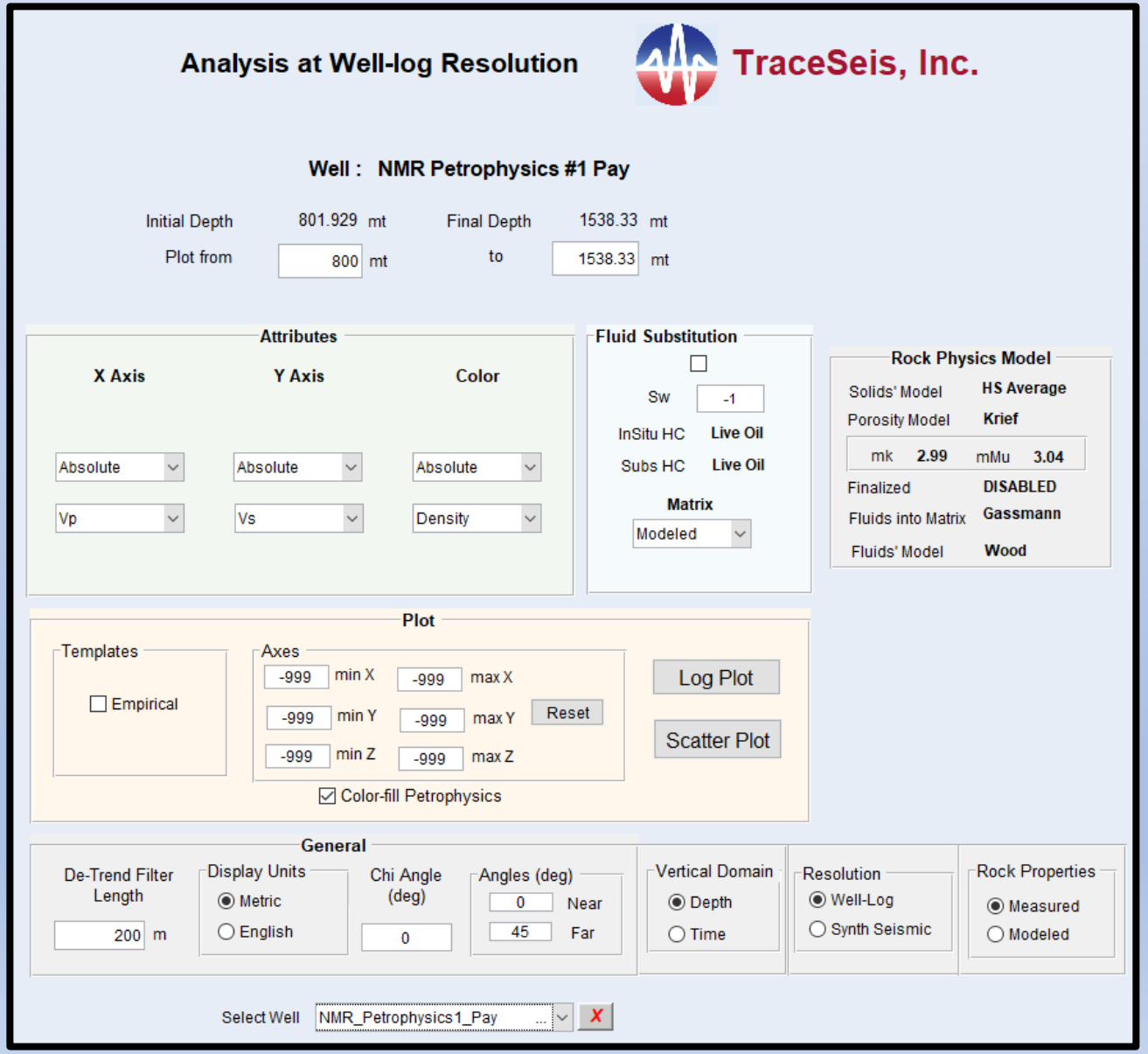

Scatter and log plots of rock properties, fluid properties and reservoir properties. Byproducts of the “Well-log inversion” can be displayed for some of the rock physics models

Rock properties and derived properties

Absolute	Relative	Reflectivities
Vp	Vp	Vp
Vs	Vs	Vs
Density	Density	Density
BritIndx	E	E
E	E*Rho	E*Rho
E*Rho	K*Rho	K*Rho
K*Rho	Ksat	Ksat
Ksat	Lambda	Lambda
Lambda	Lambda*Rho	Lambda*Rho
Lambda*Rho	MuDry	MuDry
MuDry	Mu*Rho	Mu*Rho
Mu*Rho	Ip	Ip
Ip	PModulus	P-Modulus
PModulus	Poisson	Poisson
Poisson	Is	Is
Is	vp/vs	vp/vs
vp/vs		
	ELASTIC	SHUEY
ELASTIC	EI near	Ro
EI near	EI far	Go
EI far	GI	C
GI		
		STACKS
		Stack
		Near Stack
		Far Stack

Some of the fluid properties available

- sw
- HC
- Brine
- FLUIDS MIX
- k fluids mix
- Density fluids mix
- Vp fluids mix
- ENVIRONMENTAL PROPERTIES
- Pressure
- Temperature
- IN SITU FLUID PROPERTIES
- k in situ Live Oil
- Density in situ Live Oil
- Vp in situ Live Oil
- SG in situ Live Oil
- API in situ Live Oil
- GORin situ Live Oil

Byproducts of WLI for some of the models

- KBiot
- KdryExp
- Kdry (Gassmann)
- Kdry Fixed (Gassmann)
- Kdry (Model)
- Kdry/Ko (Gassmann)
- Kdry/Ko (Model)
- Ko
- MuBiot
- MuDryExp
- MuDry (Gassmann)
- MuDry (Model)
- MuDry/Muo (Gassmann)
- MuDry/Muo (Model)
- Muo

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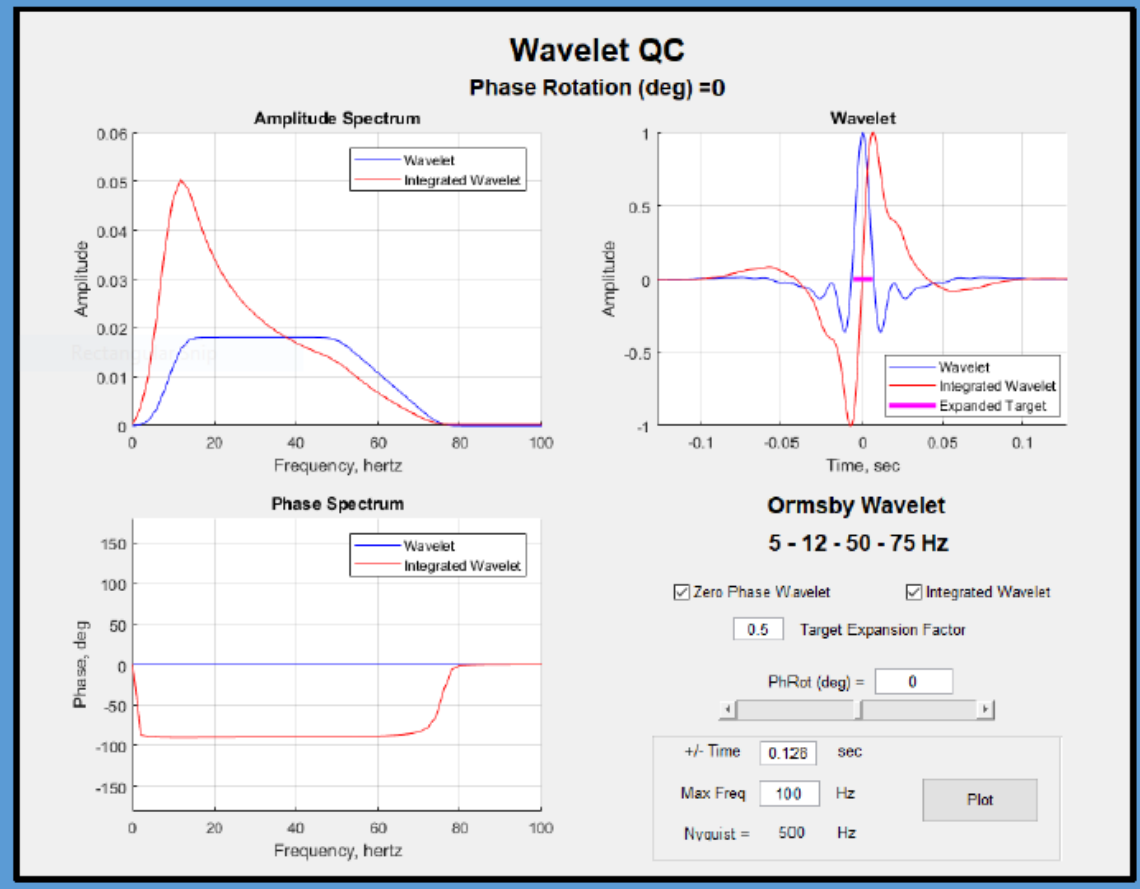

Analysis at seismic resolution
Wavelet QC

SeisRP: Analysis at well-log and seismic resolution

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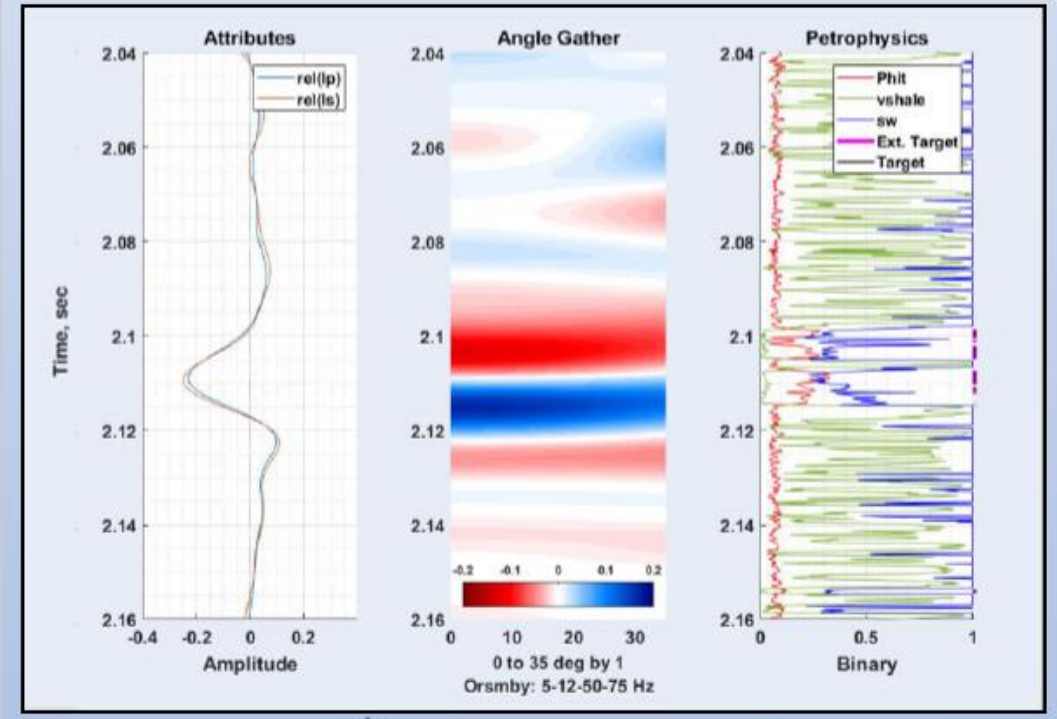
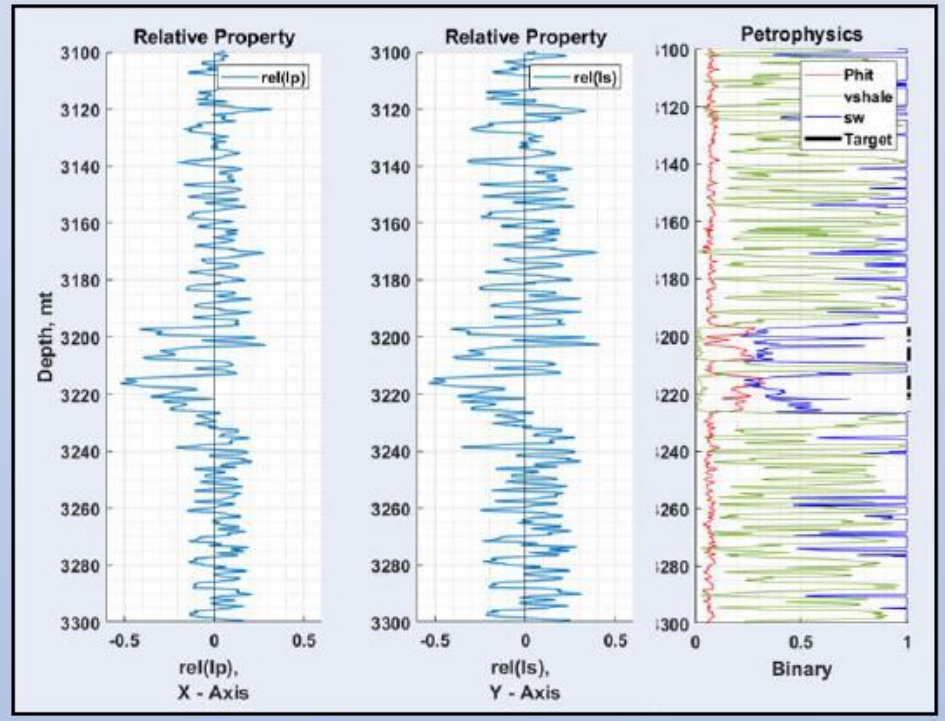


Relative P-impedance and Relative S-Impedance

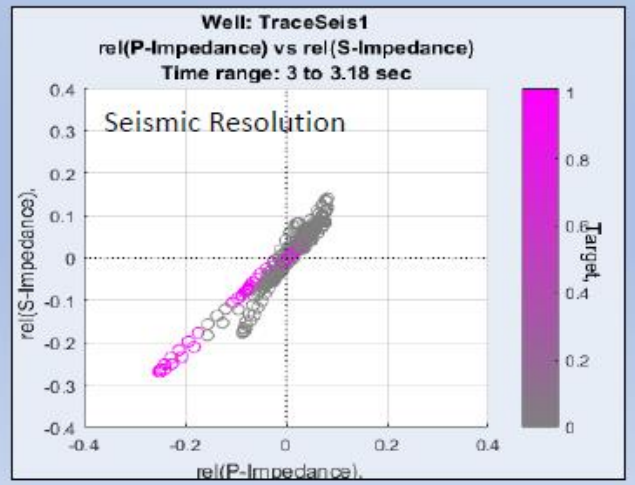
In depth at well-log resolution

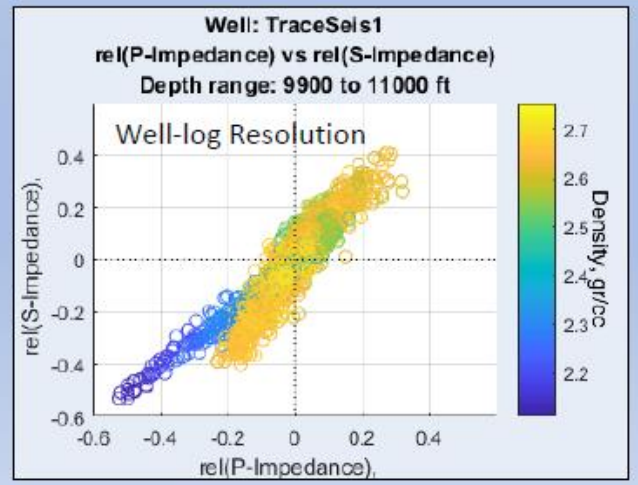
In time at seismic resolution (Δt = 1msec)

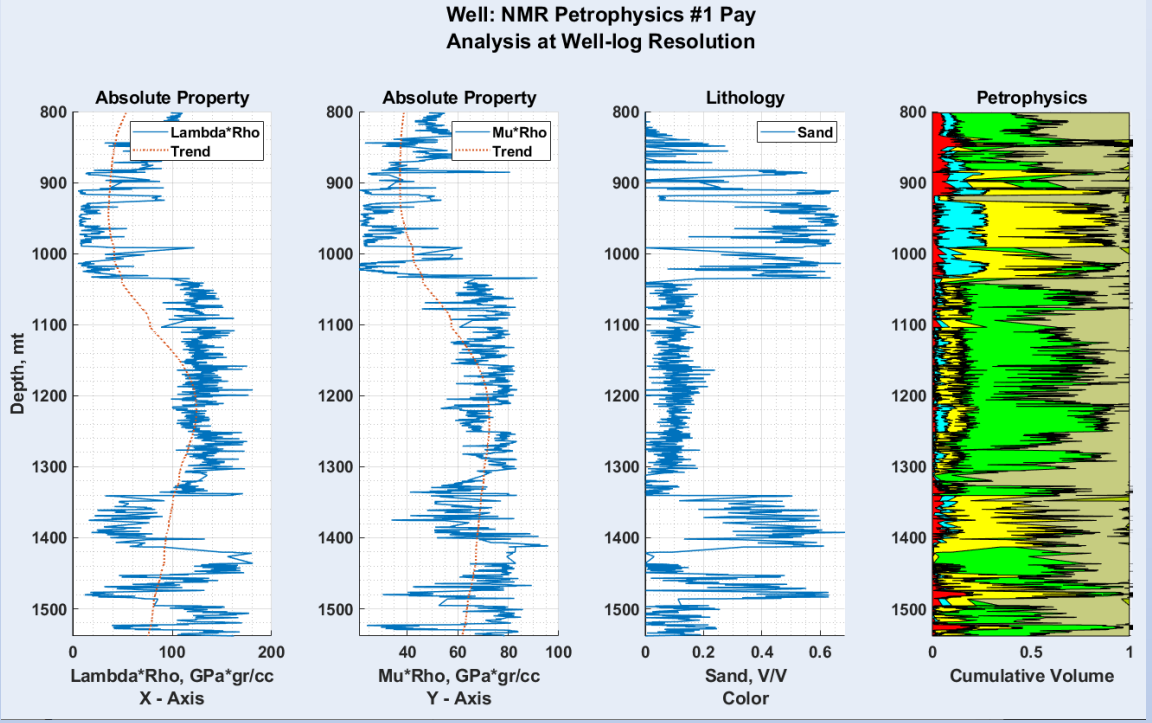


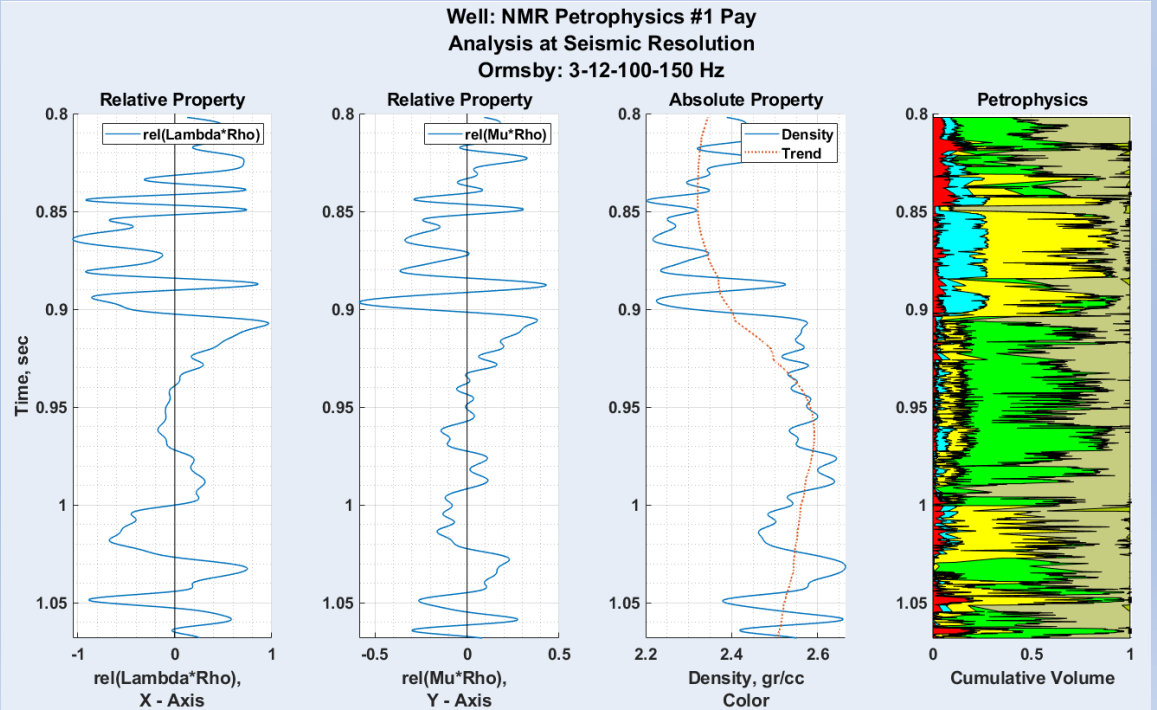
Reflectivity in the angle gather shows a trough and a peak in top and base reservoir respectively.

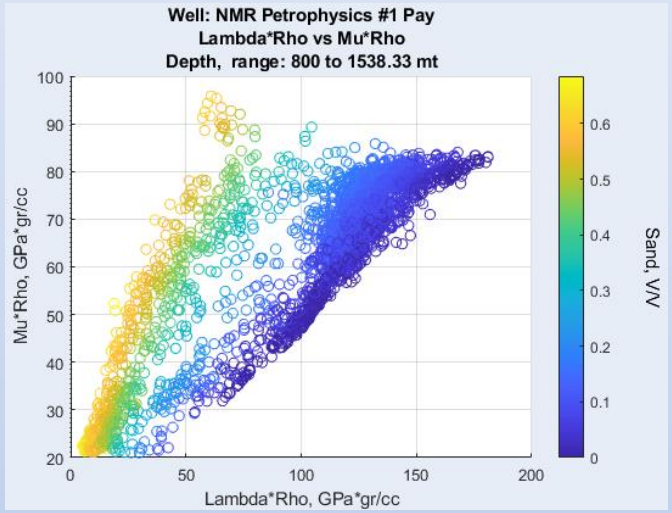
Relative Ip and relative Is are interval properties

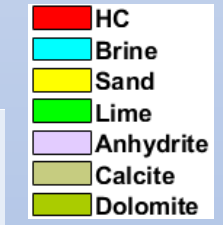


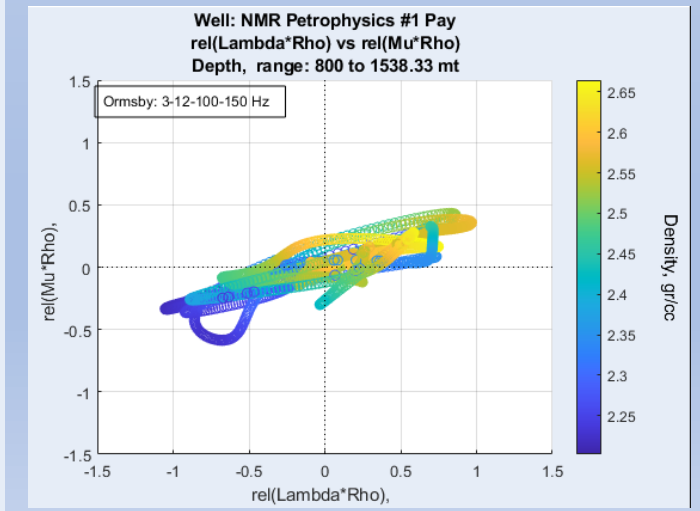












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Upper two images show log and scatter plots of $\lambda\rho$, $\mu\rho$ and Sand V/V.

Depth domain and well-log resolution.

SeisRP: Analysis at well-log and seismic resolution

Lower two images show log and scatter plots of rel($\lambda\rho$), rel($\mu\rho$) and density.

Time domain and seismic resolution.

SeisTool: Seismic – Rock Physics Tool

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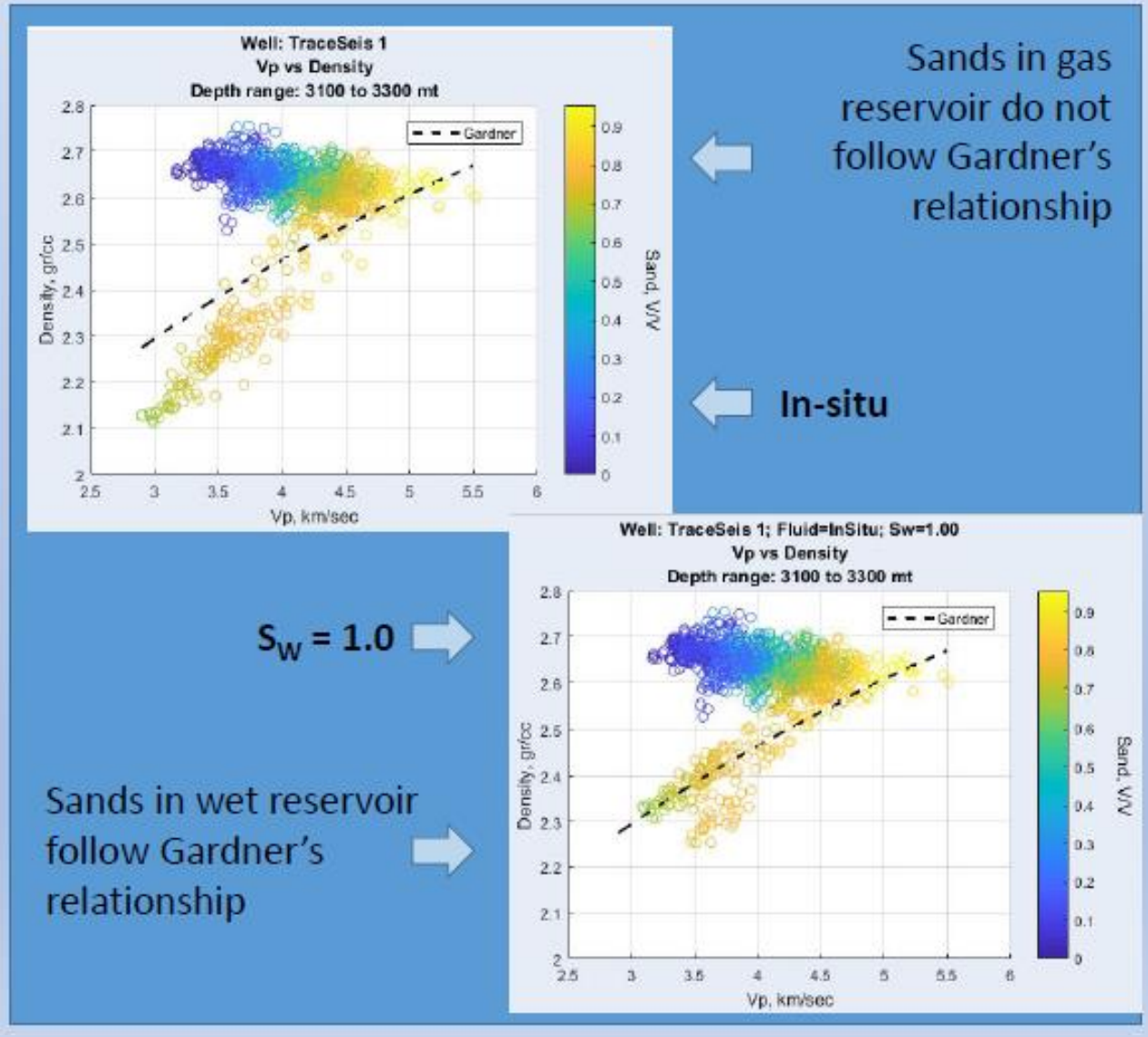

SeisRP: Fluid Properties

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Fluids Analysis

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Well: NMR Petrophysics #1 Pay

Hydrocarbons

In-Situ

Hydrocarbons: ○ Gas ○ Dead Oil ◉ Live Oil

Live Oil Properties: 23 API; 85 GOR; 0.6 Gas SG

Replacement

Hydrocarbons: ○ Gas ○ Dead Oil ◉ Live Oil

Live Oil Properties: 23 API; 85 GOR; 0.6 Gas SG

Non-hydrocarbon

◉ Brine ○ Water

Environment (P and T) and Brine Salinity

Depth-variant

	At Surface		Gradient	
Pressure	0.101325	MPa	0.0098	MPa/mt
Temperature	14	oC	0.027	oC/mt
Brine Salinity	0	ppm	40	ppm/mt

Constant

Pressure	12.003	MPa
Temperature	46.791	oC
Brine	48579	ppm

Execute/Save

Execute | Save | Reset to Initial

☑ Color-Fill Petrophysics

Fluids' Mixing Law : ◉ Wood ○ Brie

General

Display Units: ◉ Metric ○ English

Select Well: NMR_Petrophysics1_Pay

Physical Properties of Fluids

InSitu Hydrocarbon: rho 0.8049 gr/cc; k 1.108 GPa; Vp 1.173 km/se

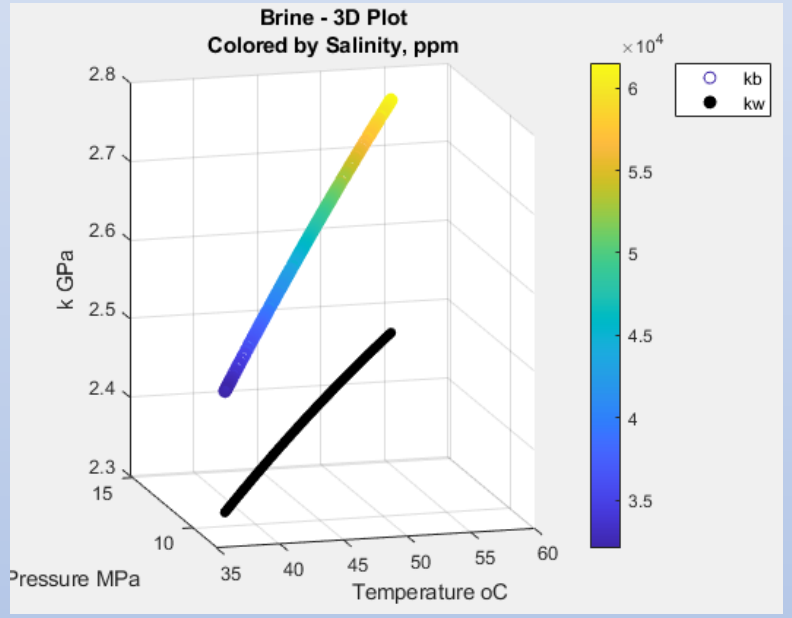
Replacement Hydrocarbon: rho 0.8049 gr/cc; k 1.108 GPa; Vp 1.173 km/se

Brine / Water: rho 1.028 gr/cc; k 2.652 GPa; Vp 1.606 km/se

Set Values as Depth Invariant

Plot

☐ Fluid Properties
☑ Depth Variant Environment
☐ QC Graphs
☐ Rock Properties

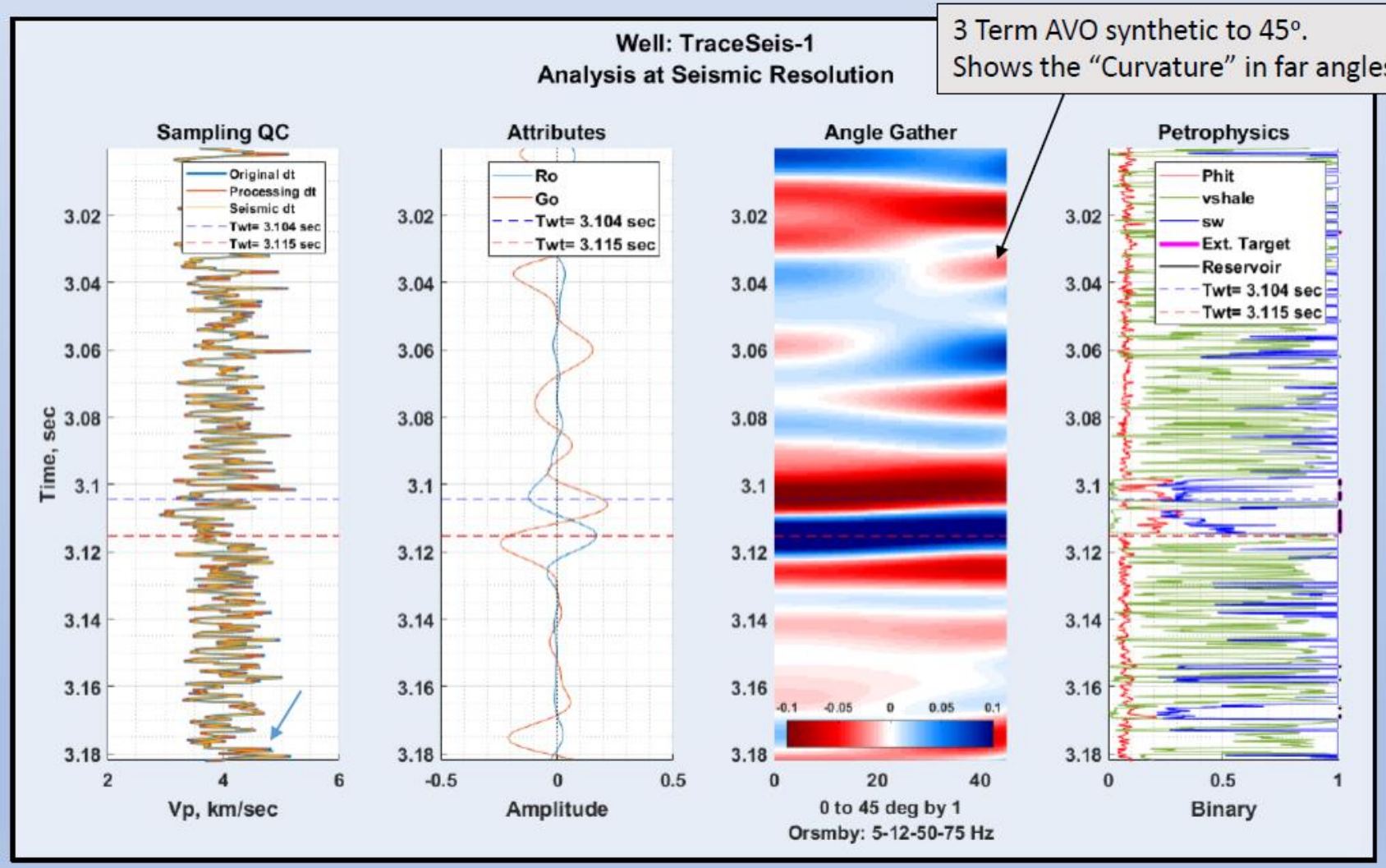


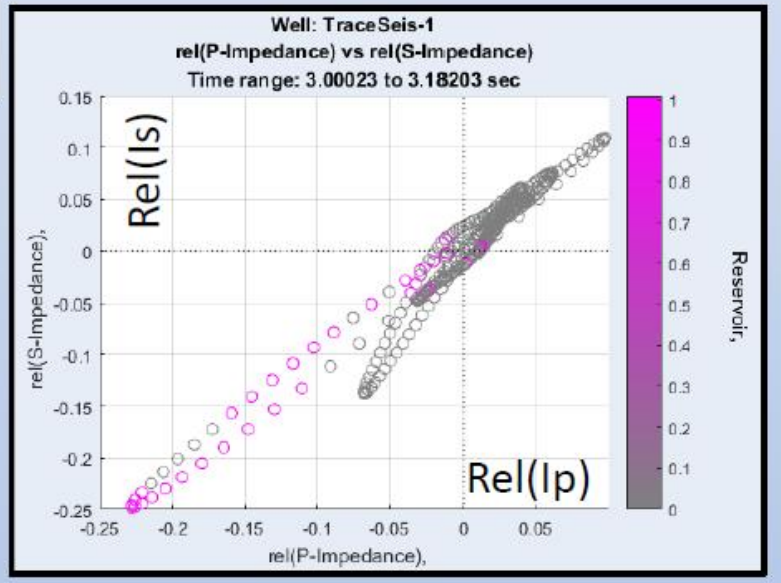
Reservoir fluids' composition (GOR, API, SG, salinity) and environmental variables (pressure and temperature) are used to compute bulk moduli and density of fluids.

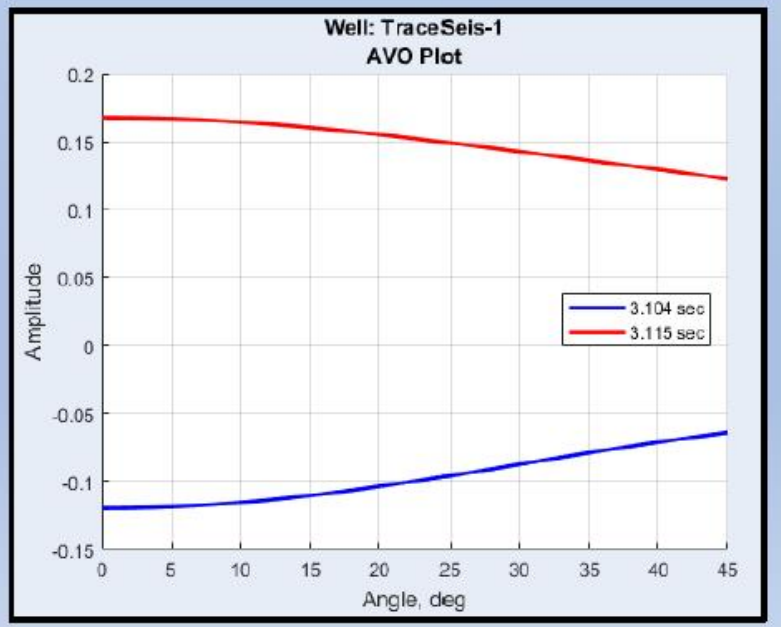
Properties for three fluids are computed: in-situ hydrocarbons, replacement hydrocarbons, and brine.

Depth variant or constant fluid properties can be computed

SeisRP – Fluid substitution. In-situ

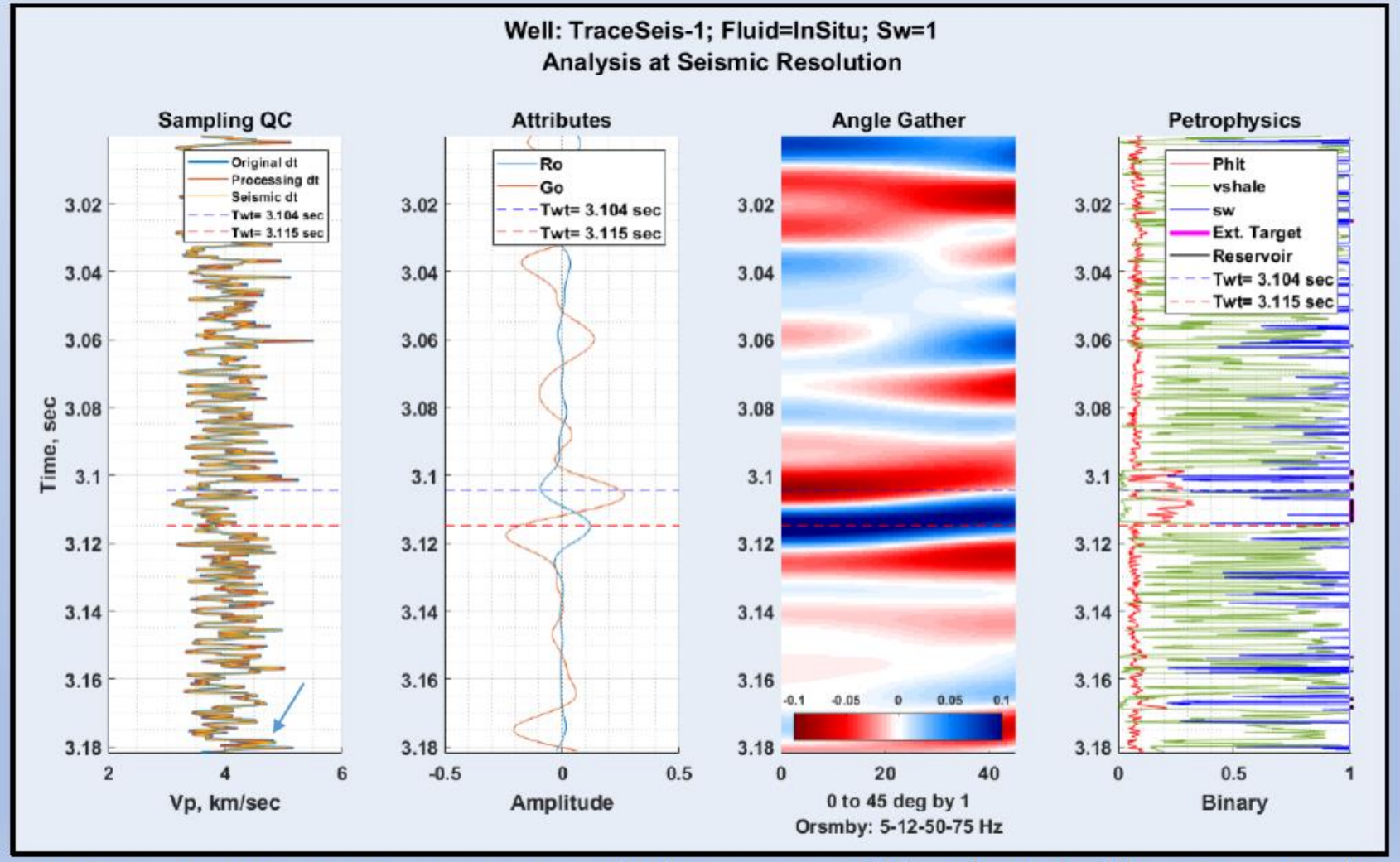


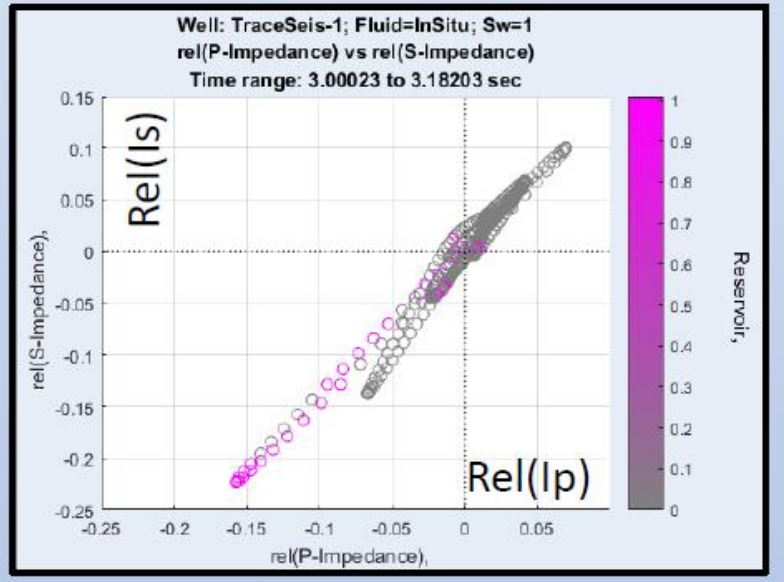


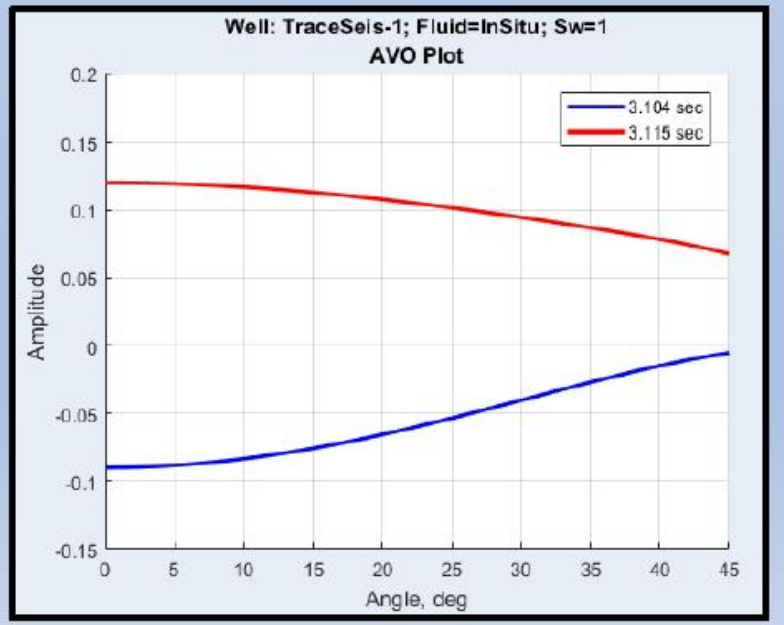


In-situ fluids. The AVO extracted at the red and blue horizontal lines in tracks 1 and 2 correspond to a class 4 anomaly, as observed in the plot at right

SeisRP – Fluid substitution. Sw = 1.0







Water saturation = 1.0. Compare with the previous slide. The light-blue arrow in the lower part of track 1 shows the slight time difference between the in-situ (previous slide) and wet reservoir (this slide) associated to fluids with different velocities

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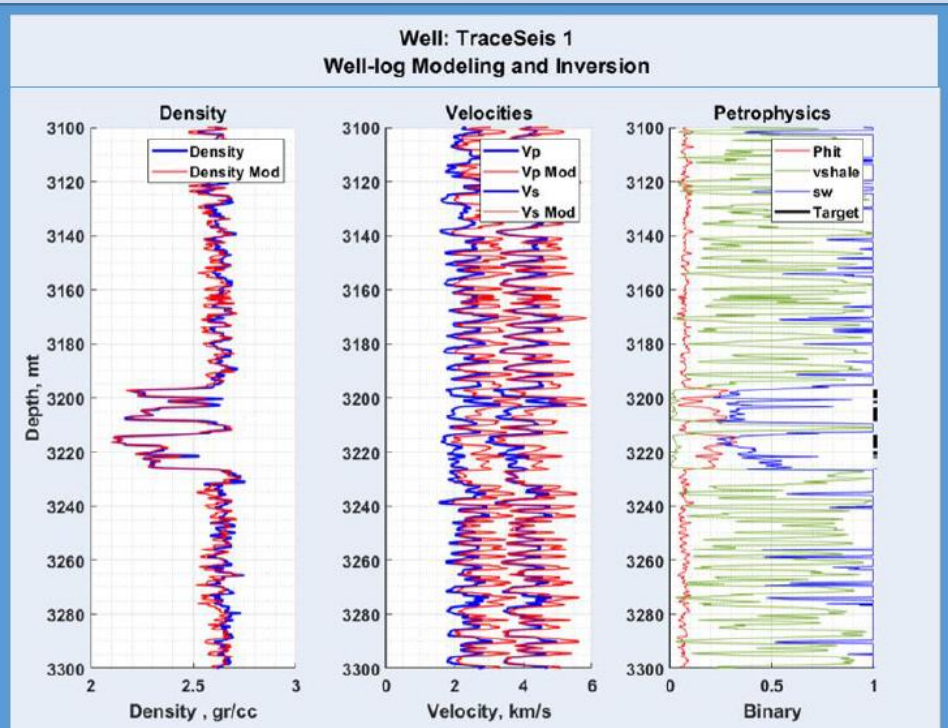
  - Estimates moduli and densities of rock constituents through non-linear inversion of rock properties' logs
  - Computes rock properties for perturbations of the in-situ reservoir properties
  - Based on effective media theory. Minimum heuristic or empirical relationships are used
- SeisChar
- Utilities



	Mineral	k	rho	mu
1	Sand	38	2.6500	45
2	Shale	19	2.8200	12

	Fluid	k	rho
1	Gas	0.0702	0.1760
2	Brine	2.6560	0.9941

Well-log Modeling

The red curves in tracks 1 and 2 are the modeled ρ, Vs and Vp using the moduli and densities in the tables above. The blue lines are measured logs

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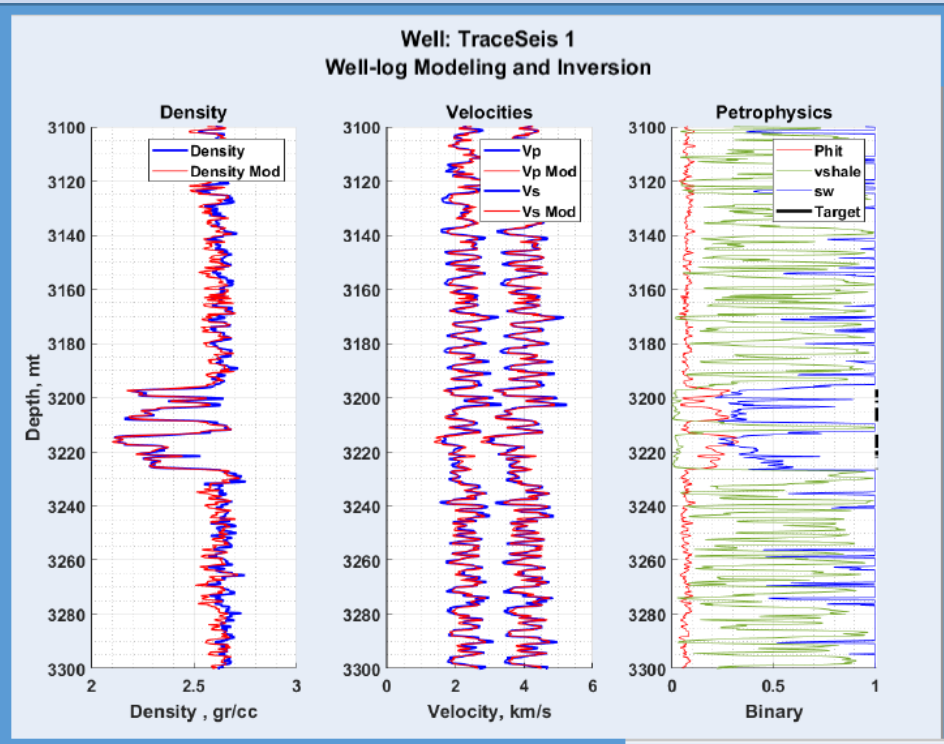
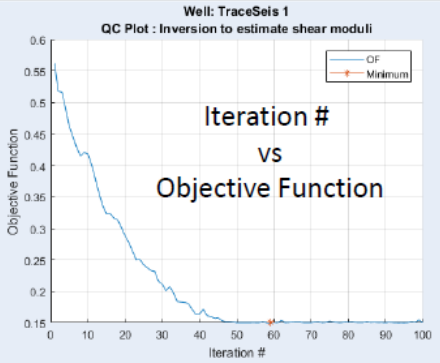


Well-log Inversion

The modeled curves are a close match to the measured ones after moduli and densities are computed through non-linear inversion of rock properties.



SeisMod: Well-log inversion

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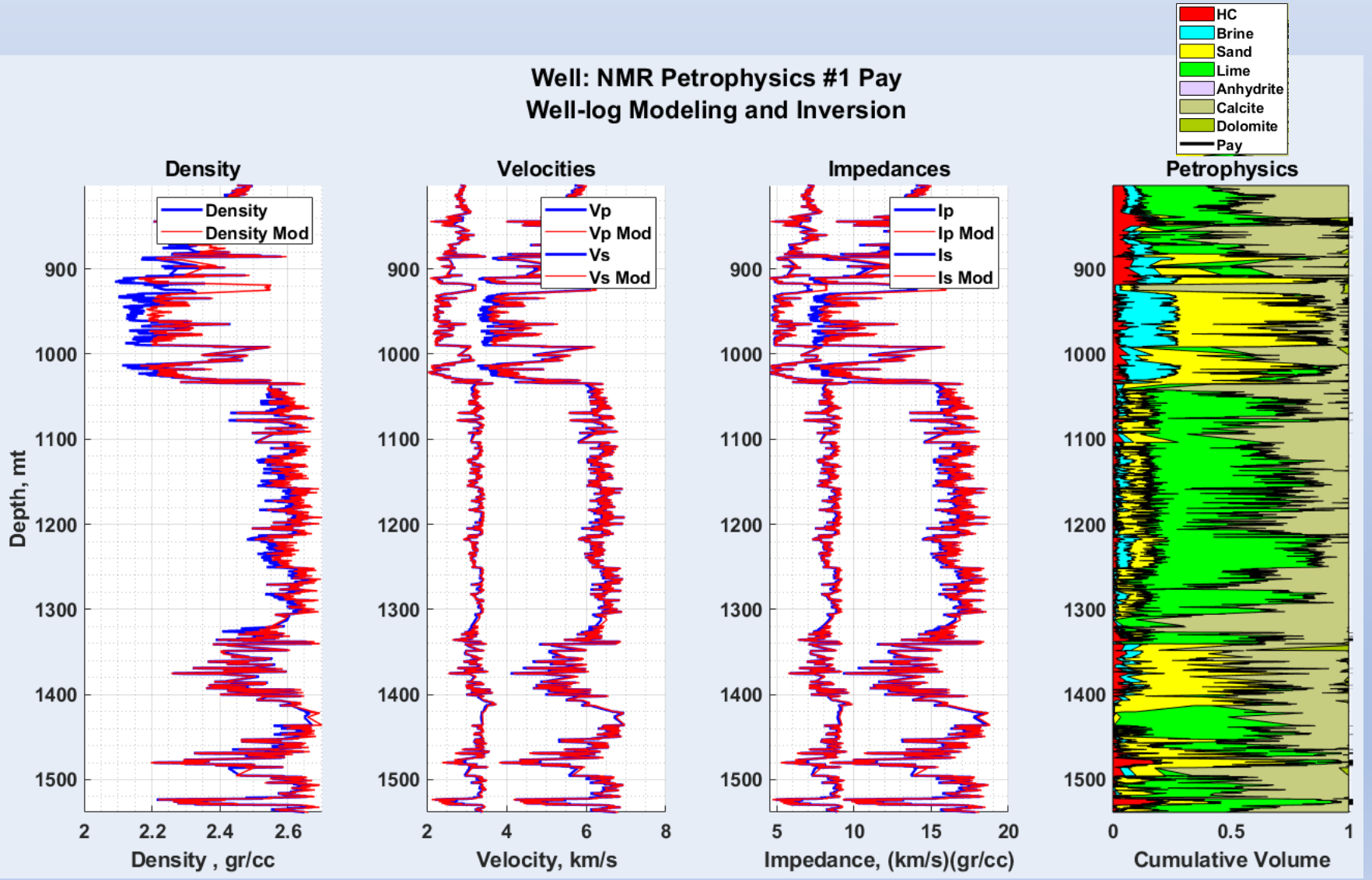
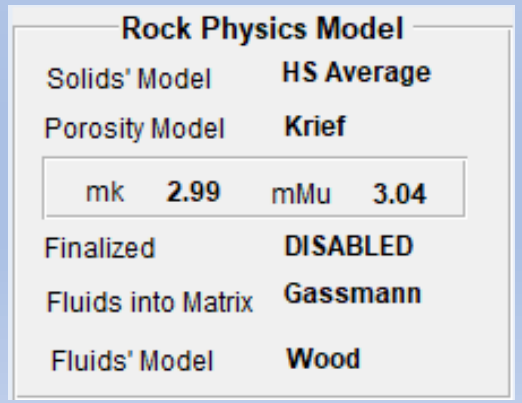


	Mineral	k, GPa	rho, gr/cc	mu, GPa	Organic
1	Sand	36.2440	2.6639	46.2414	No
2	Lime	97.9846	2.7515	35.0867	No
3	Anhydrite	59	2.9700	30	No
4	Calcite	71.7529	2.5849	30.1709	No
5	Dolomite	84.1264	2.9100	48.4298	No

The image at left shows the **modeled** and **measured** logs of a multi-mineral well. Moduli and densities (table above) are computed through well-log inversion.

The image below shows the effective media relations used.



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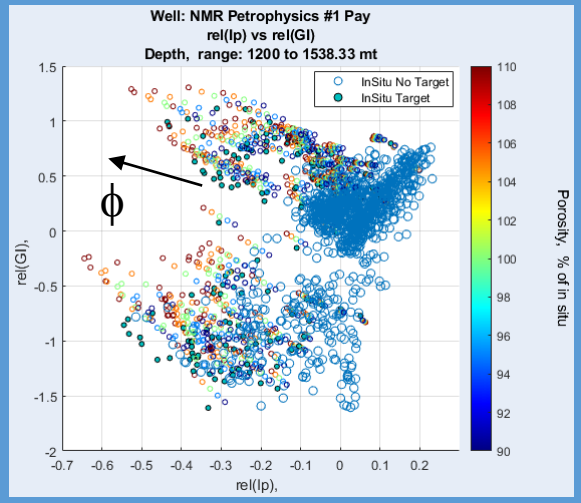

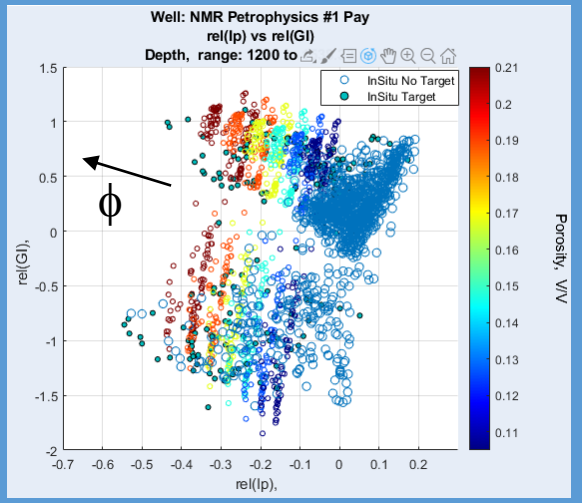

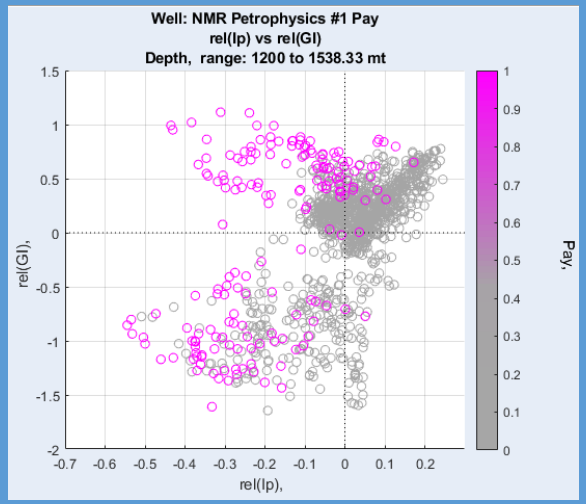

Cross-plots show relative acoustic impedance (rel(AI)) versus relative gradient impedance (rel(GI)).

Porosity is modified:

- **Percent of in-situ (upper left) From 90% to 110%**
- **Constant porosities (upper right) from mean minus one standard deviation to mean plus one standard deviation.**

Perturbations are made in pay points (magenta points at left)

SeisMod: Well-log Modeling

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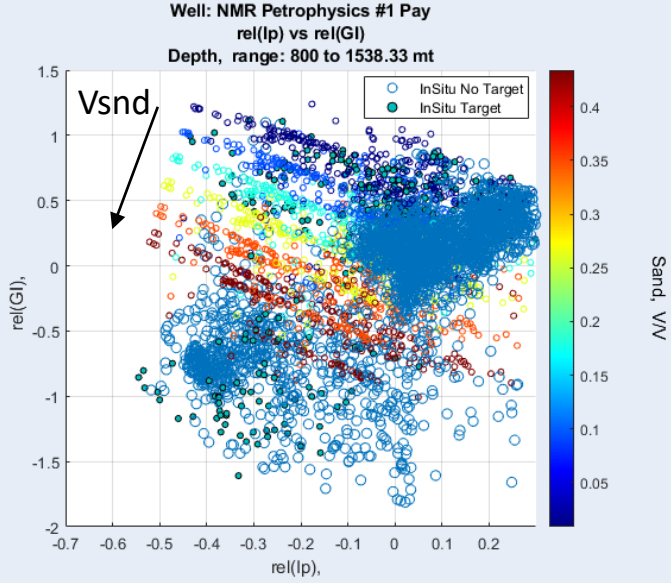
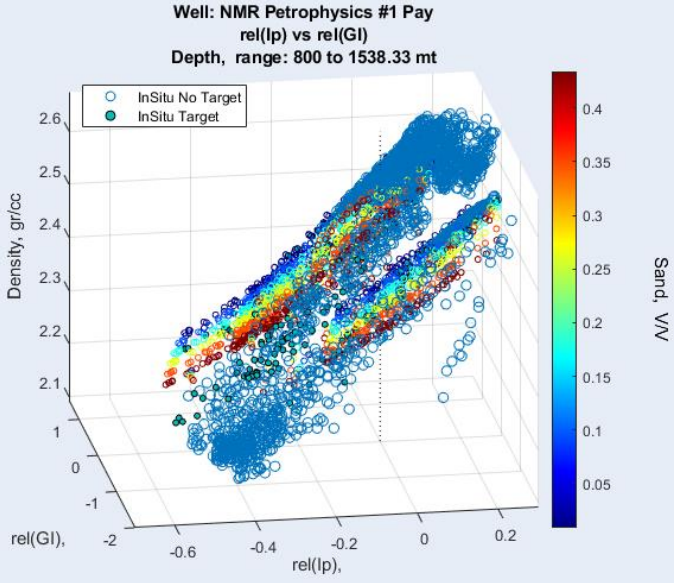
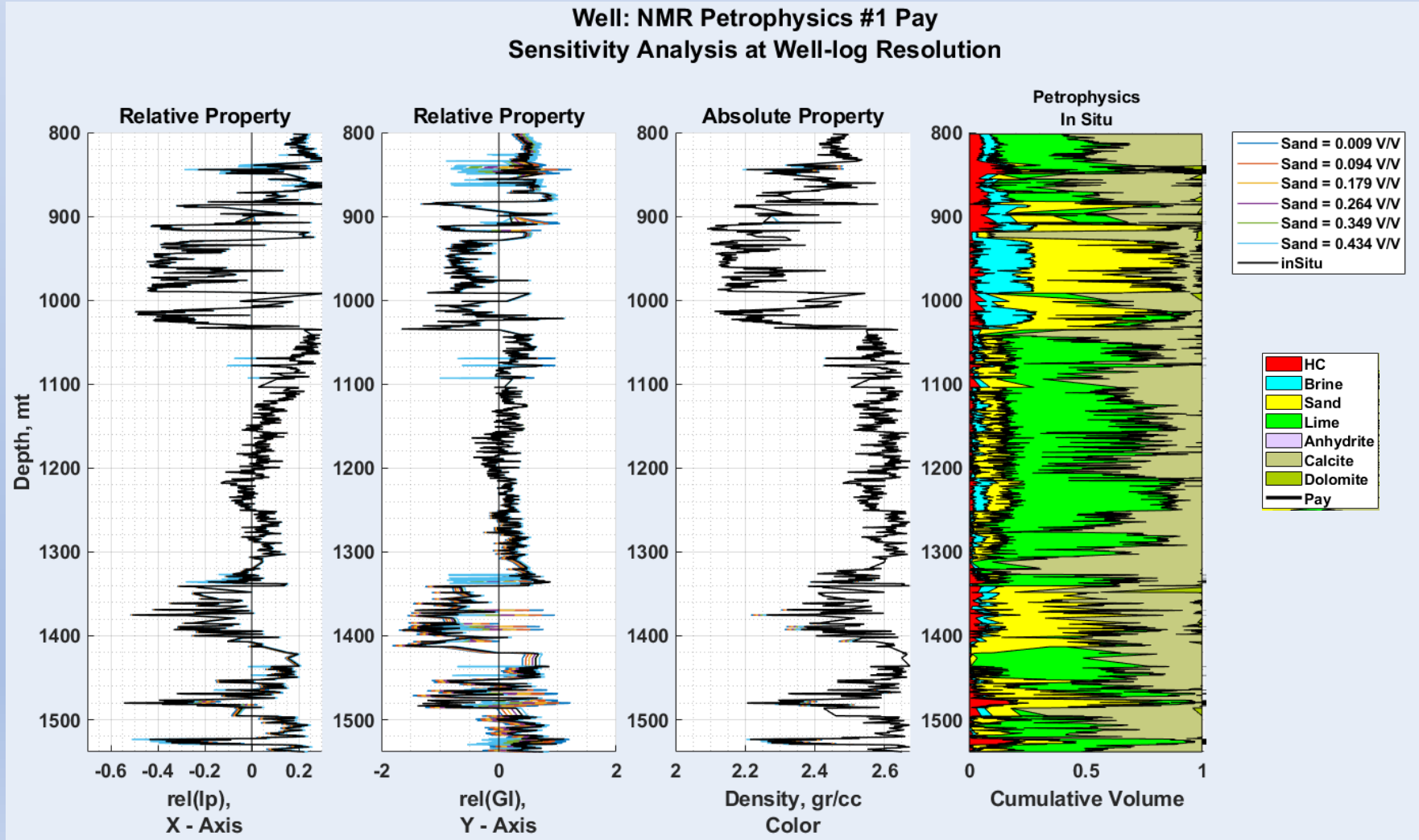




Sand percent is modified in pay-flag points. From mean minus one standard deviation to mean plus one standard deviation. The 3D cross-plot (lower left) shows different rock properties for shallow and deep reservoirs



SeisMod: Well-log Modeling

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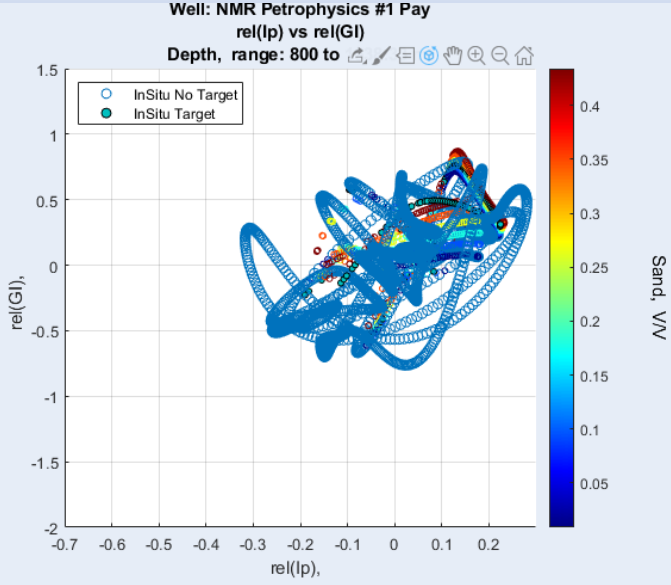
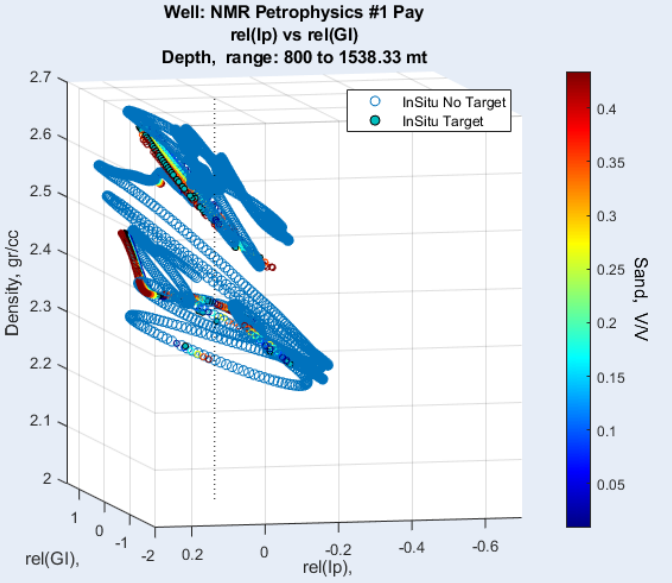
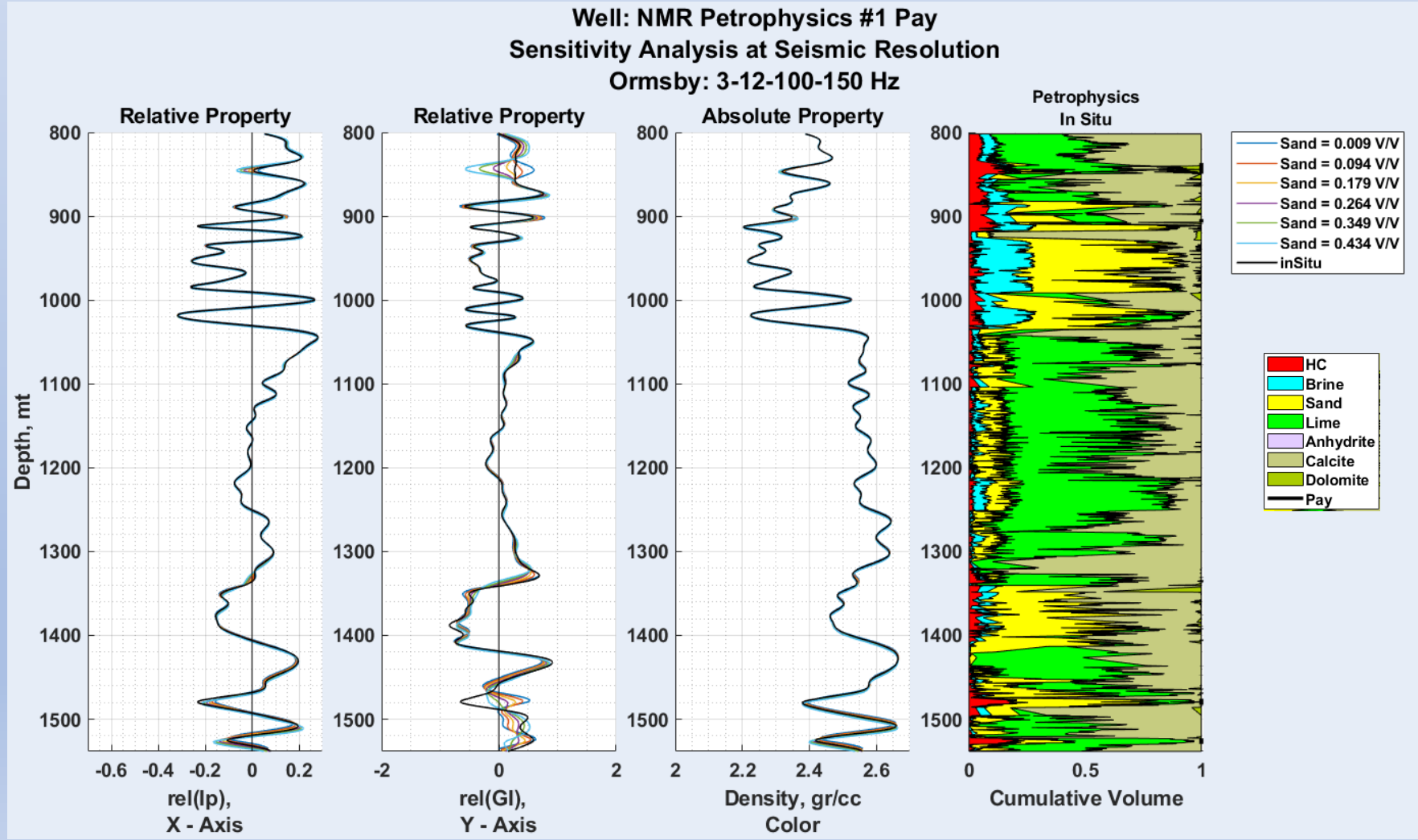




Sand percent is modified in pay-flag points and rel(Ip), rel(GI) modeled at seismic resolution for different sand volumes. The pay points are few and sparse, which results in poor lithology discrimination in cross-plots (compare with previous slide). Upper and lower reservoirs appear separated in the 3D cross-plot.



SeisTool: Seismic – Rock Physics Tool

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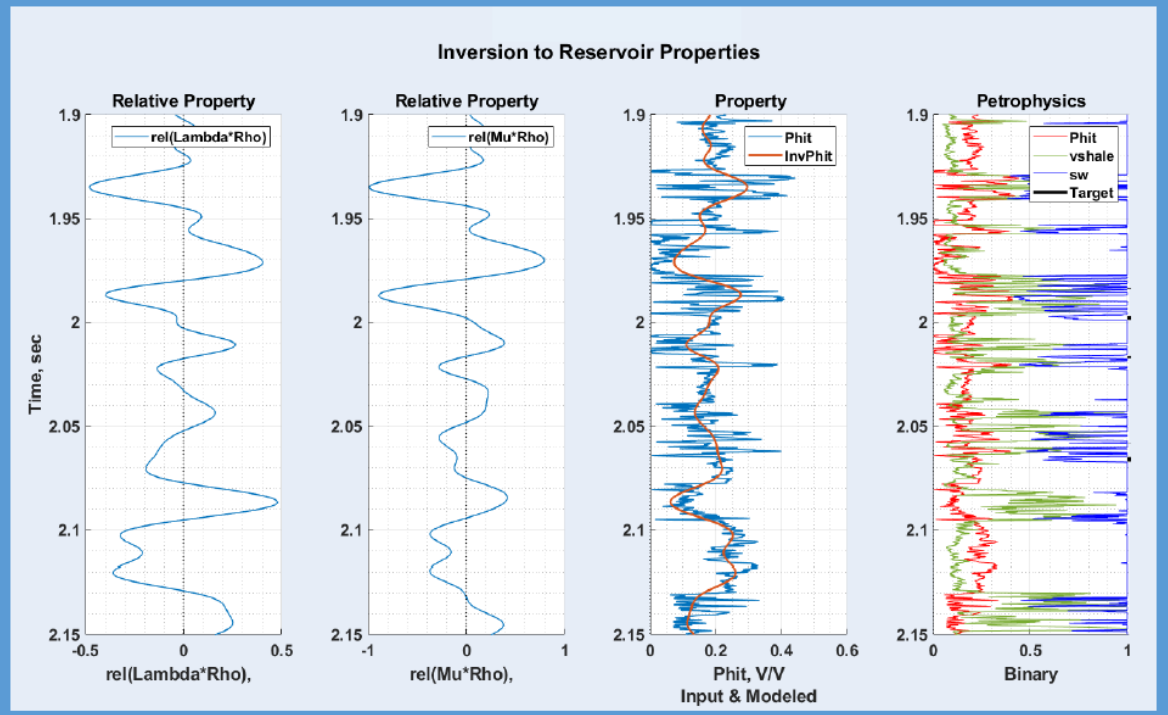
- SeisRP
- SeisMod
- **SeisChar**
  - Sensitivity bar-graph. Under development. Evaluates the weight that selected attributes have in the estimation of a given reservoir property. Results are presented in bar-graph
  - **Reservoir Properties. Estimate reservoir properties through combinations of rock properties and derived properties. Compute the parameters to estimate reservoir properties from seismic**
  - Probability Analysis. Under development
- Utilities



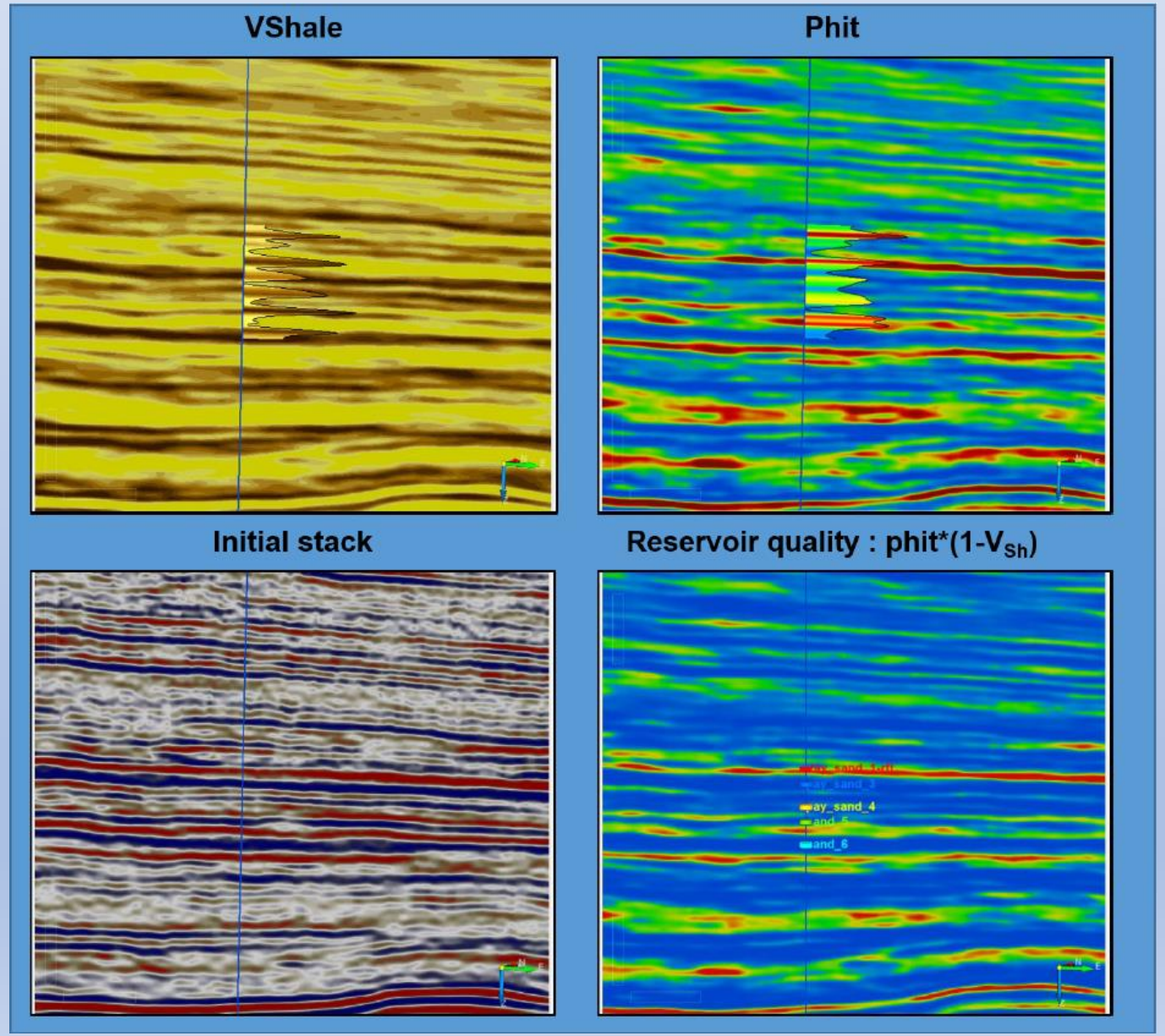
Analysis at seismic resolution (binary petrophysical evaluation)

Relative λρ (track 1) and relative μρ (track 2) are combined to estimate porosity (brown curve in track three).

The linear combination of relative rock properties is equivalent to a coordinate rotation (150°) of attributes

```
Phit = +0.1623 +0.1475*ROT[rel(Lambda*Rho), rel(Mu*Rho), +150.0 deg]
```

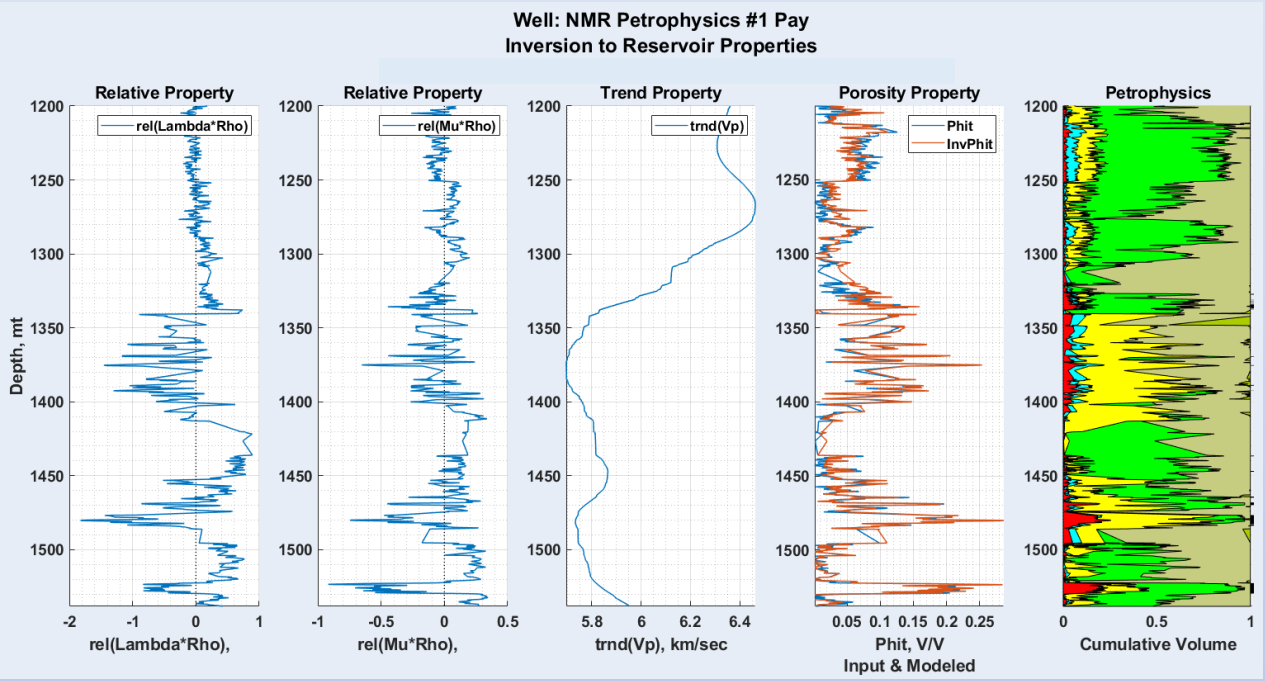
SeisChar: Reservoir Properties

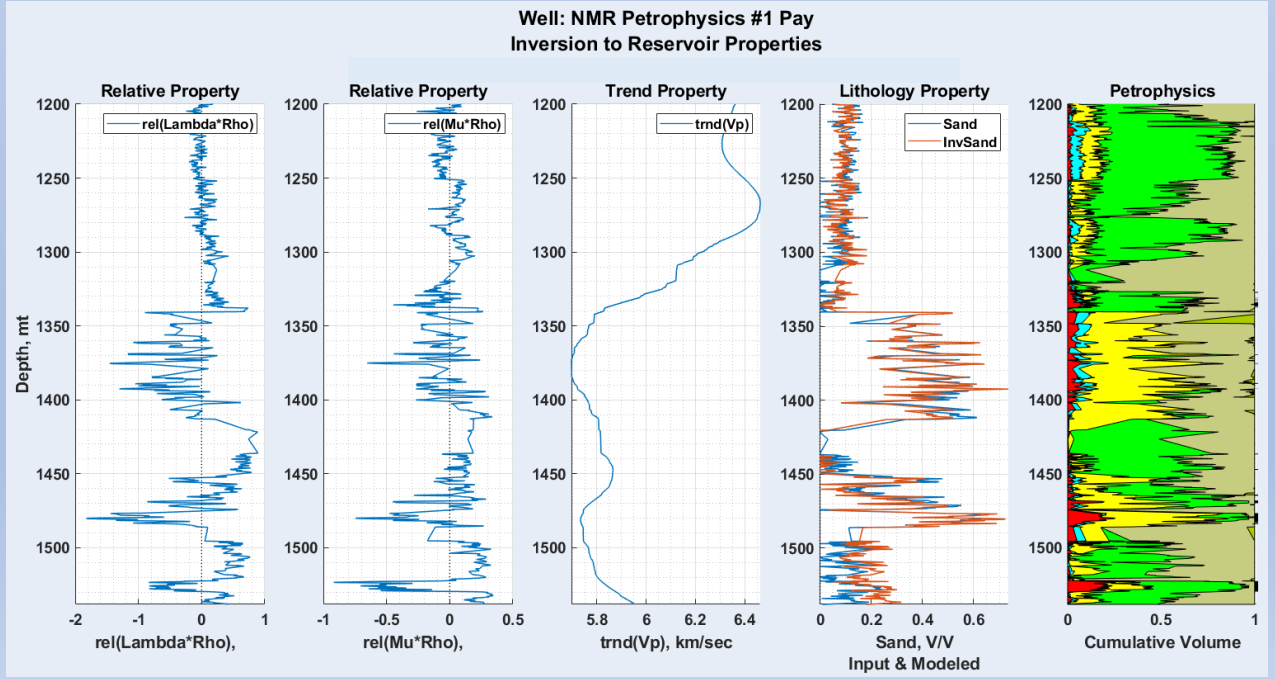


Reservoir properties from seismic

The upper images show the reservoir properties (porosity and lithology) estimated from seismic data. The log trace along the well is the reservoir property that was computed from well-log data at seismic resolution (previous slide).

The lower left image is the initial stack and the lower right is the reservoir quality computed from the porosity and lithology cubes





SeisChar: Reservoir Properties

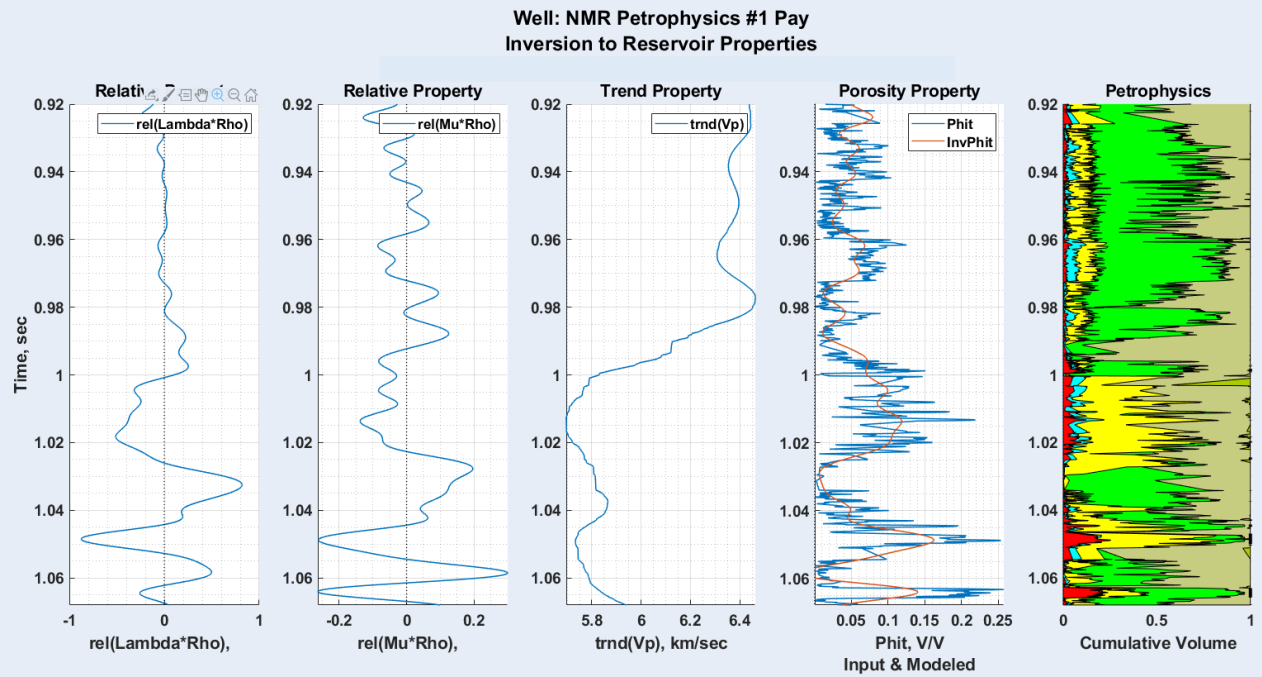
Reservoir properties in a multi-mineral well. Well-log resolution

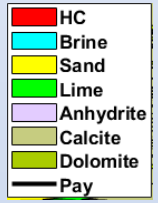
The images show the estimation of porosity and Sand volume from combinations of rel($\lambda\rho$), rel($\mu\rho$) and the low frequency trend of Vp (trend(Vp)).

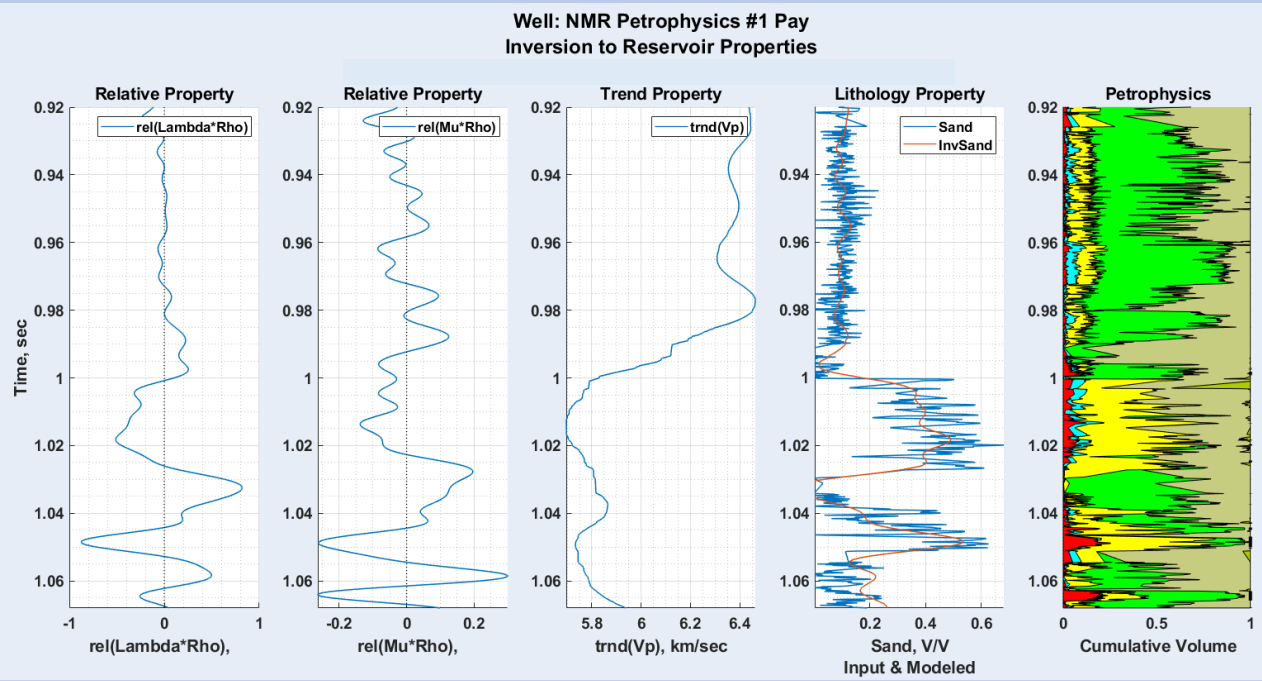
Estimation of reservoir properties required, in this well, a low frequency trend; hence the use of trend(Vp). Migration velocities can provide the low frequency trend when estimating reservoir properties from seismic data.

The brown line in the fourth track is the estimated reservoir property. The blue line in the same track is the reservoir property log

The next slide shows the equivalent estimations at seismic resolution.







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SeisChar: Reservoir Properties

Reservoir properties in a multi-mineral well. Seismic resolution

The images show the estimation of porosity and Sand volume from combinations of rel($\lambda\rho$), rel($\mu\rho$) and the low frequency trend of Vp (trend(Vp)).

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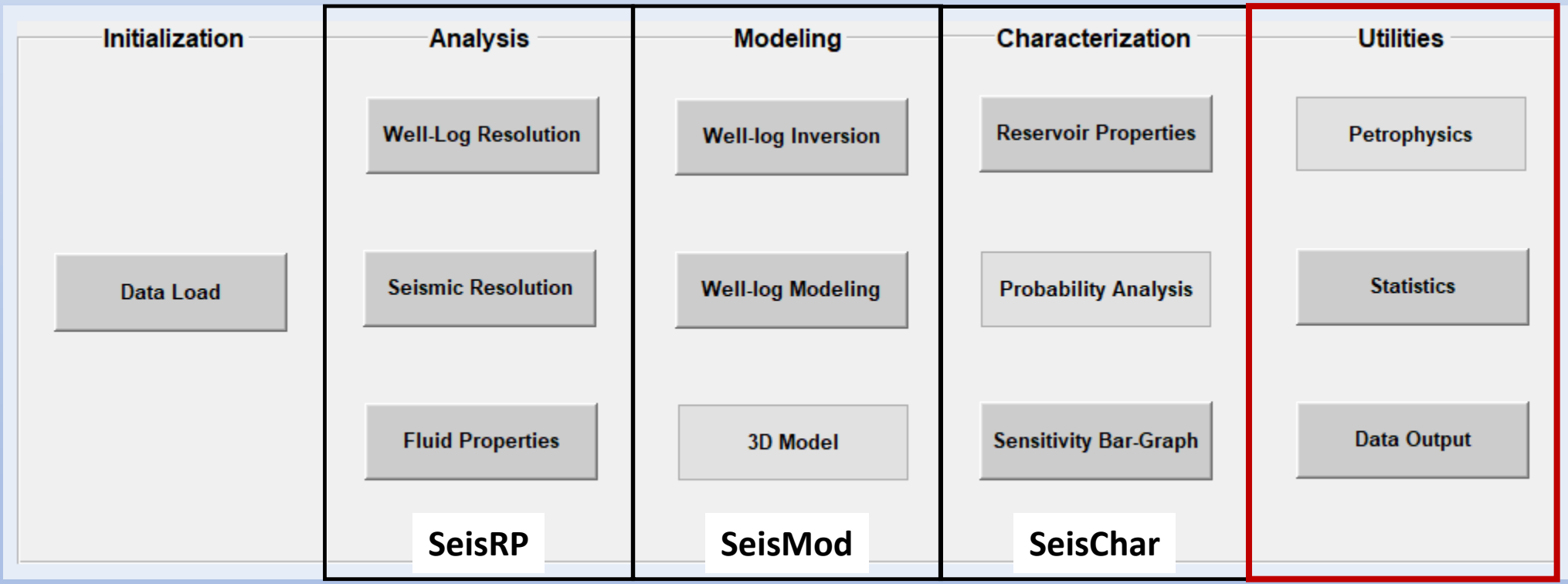
The previous slide shows the equivalent estimations at well-log resolution.

SeisTool: Seismic – Rock Physics Tool

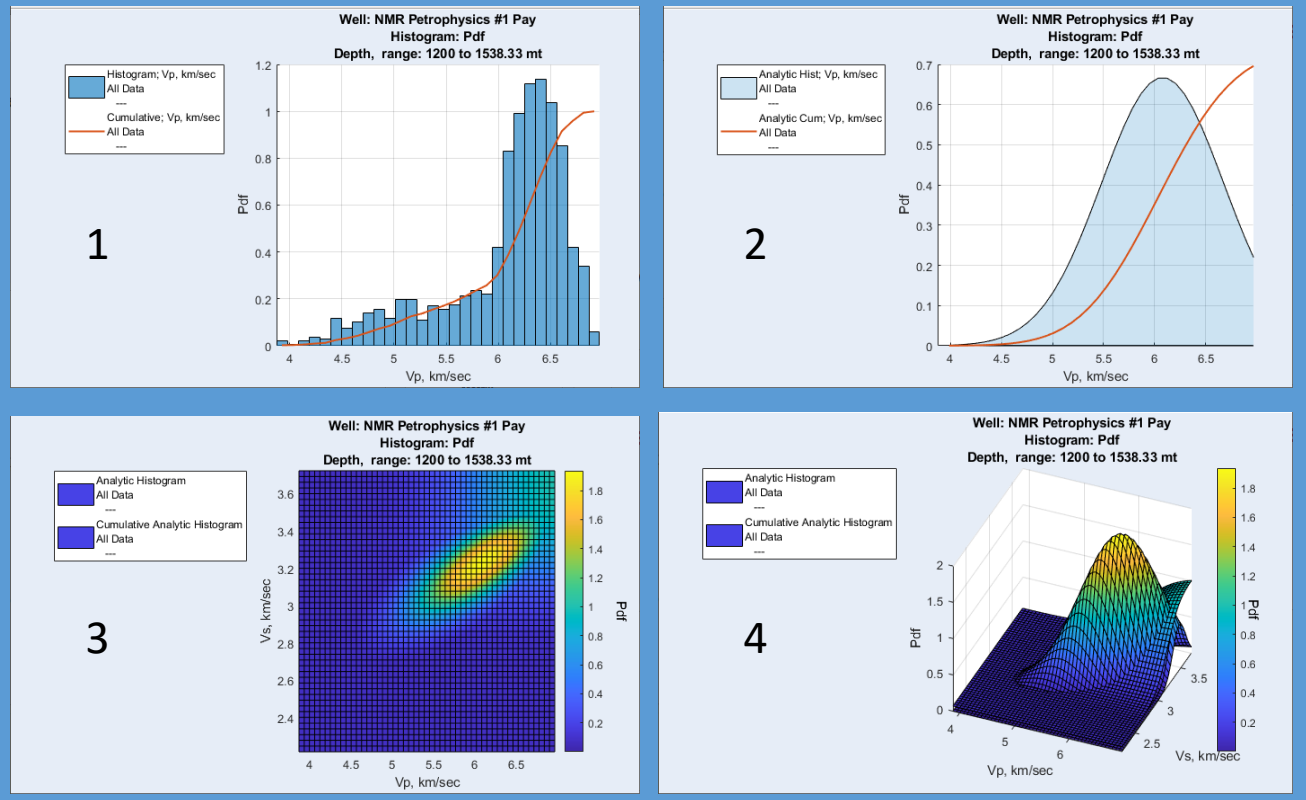
TraceSeis Inc.
Geophysical Services

- SeisRP
- SeisMod
- SeisChar
- **Utilities**



SeisTool: Utilities

- Petrophysics – Under development
- **Statistics**
  - **1D or 2D normal and cumulative histograms**
  - Analysis can be done in depth or two-way time and at well-log or seismic resolutions
  - Histogram scaling can be sample-count, pdf or probability
  - **Measured or analytic (normal distribution) analysis**
  - Can elect to evaluate pay points, non-pay points or all data in the analysis window
  - Can do analysis of rock properties for different reservoir conditions
  - For the 1D case, more than one property can be plotted in the same graph
- Data Output



1.- Measured Vp. Histogram and cumulative plots (PDF)
2.- Measured Vp. Analytic histogram. Normal distribution and cumulative plot
3.- 2D (Vp-Vs) analytic histogram. PDF and cumulative.
4.- 3D plot (isometric) of figure 3.

SeisTool: Utilities

- Petrophysics – Under development
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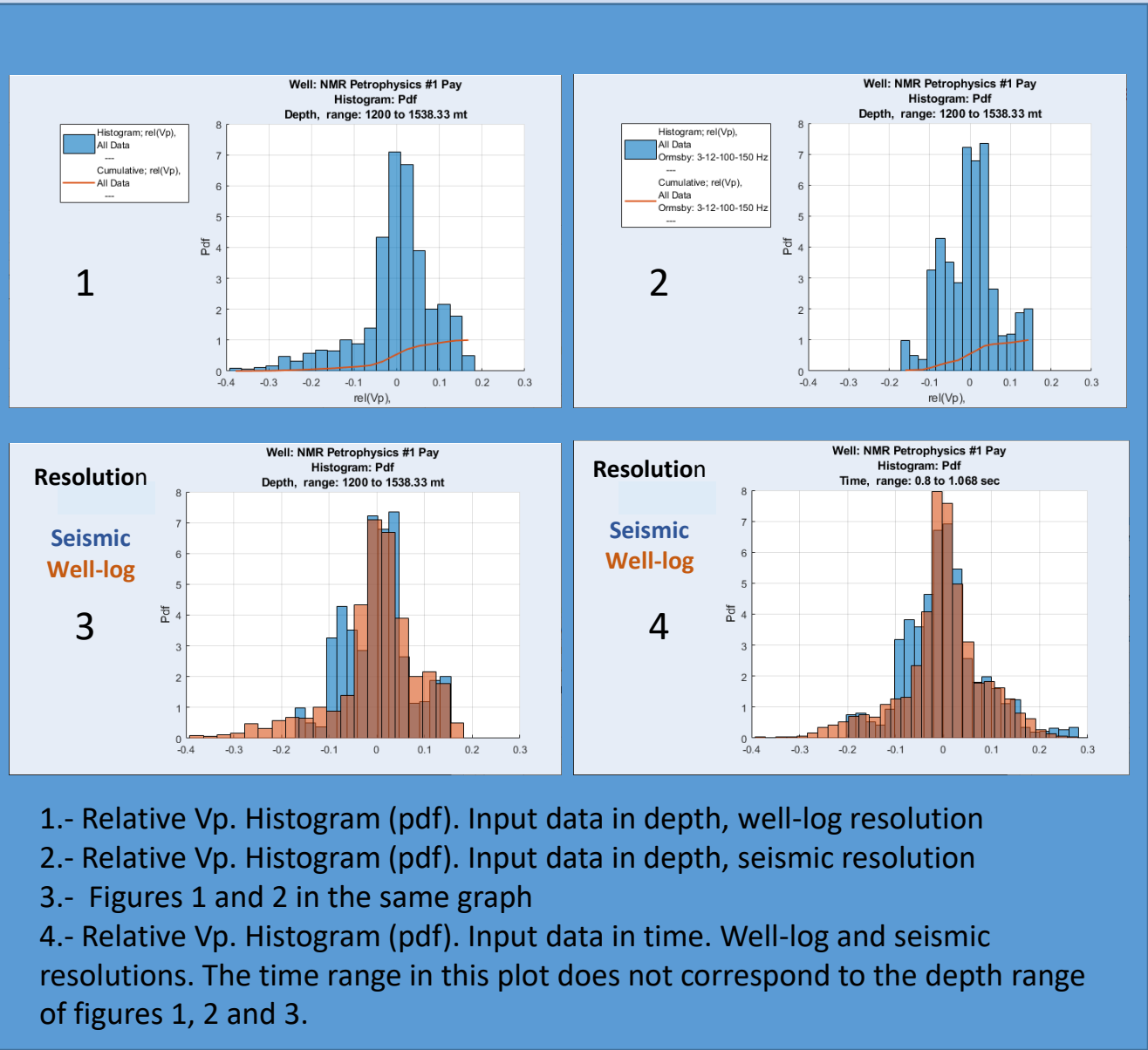

1.- Relative Vp. Histogram (pdf). Input data in depth, well-log resolution
2.- Relative Vp. Histogram (pdf). Input data in depth, seismic resolution
3.- Figures 1 and 2 in the same graph
4.- Relative Vp. Histogram (pdf). Input data in time. Well-log and seismic resolutions. The time range in this plot does not correspond to the depth range of figures 1, 2 and 3.

SeisTool: Utilities

- Petrophysics – Under development
- **Statistics**
  - 1D or 2D normal and cumulative histograms
  - Analysis can be done in depth or two-way time and at well-log or seismic resolutions
  - Histogram scaling can be sample-count, pdf or probability
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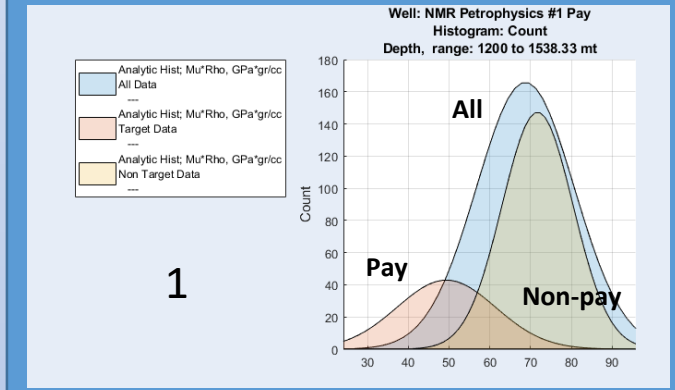

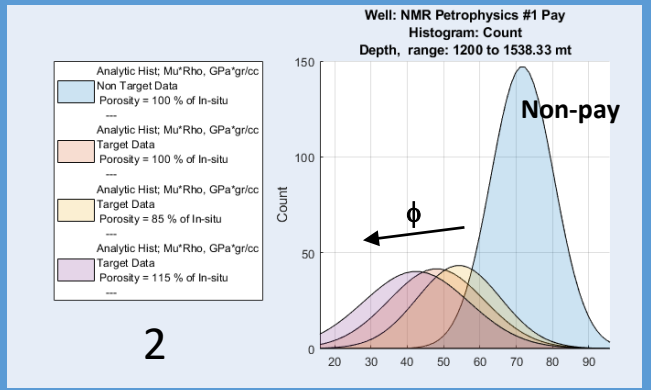

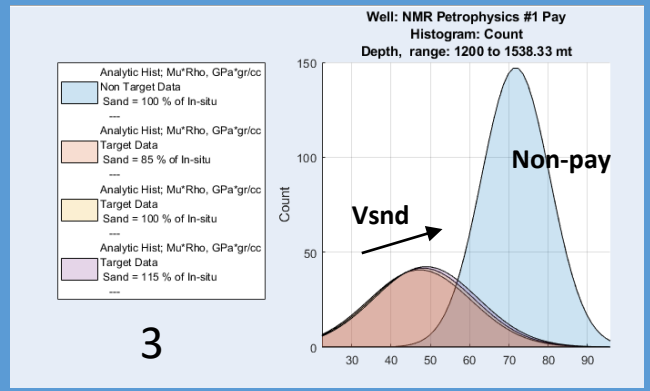

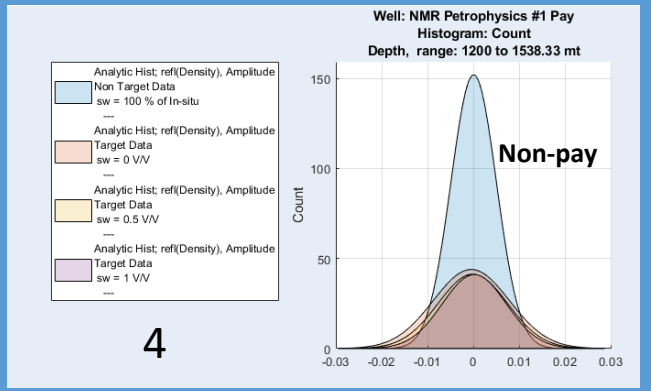

1.- μρ analytic histograms (point count). All data, non-pay and pay
2.- μρ analytic histograms (point count). Histograms for non-pay and pay points with ϕ = 85%, 100% and 115% of in-situ
3.- μρ analytic histograms (point count). Histograms for non-pay and pay points with Vsnd = 85% 100% and 115% of in-situ
4.- Density reflectivity histogram (point count). Histograms for non-pay and pay points with Sw = 0, 0.5 and 1